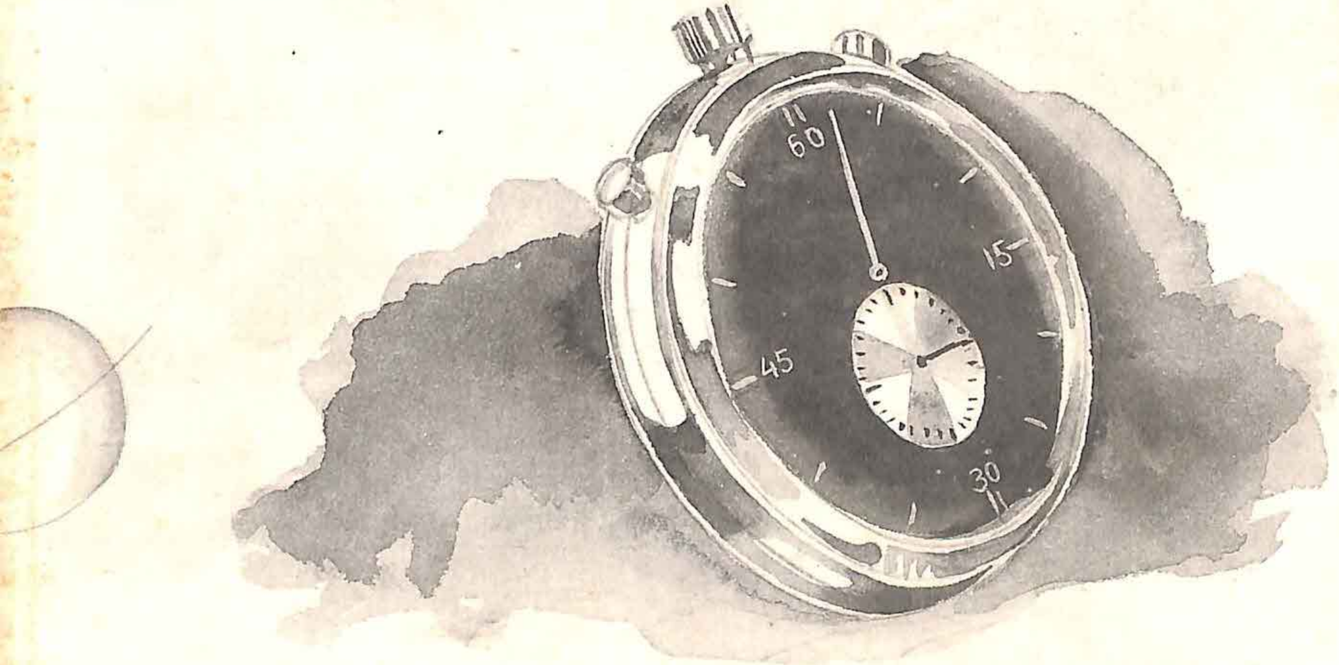
NEW MATRICULATION
PHYSICS



8

NEW MATRICULATION
PHYSICS 8

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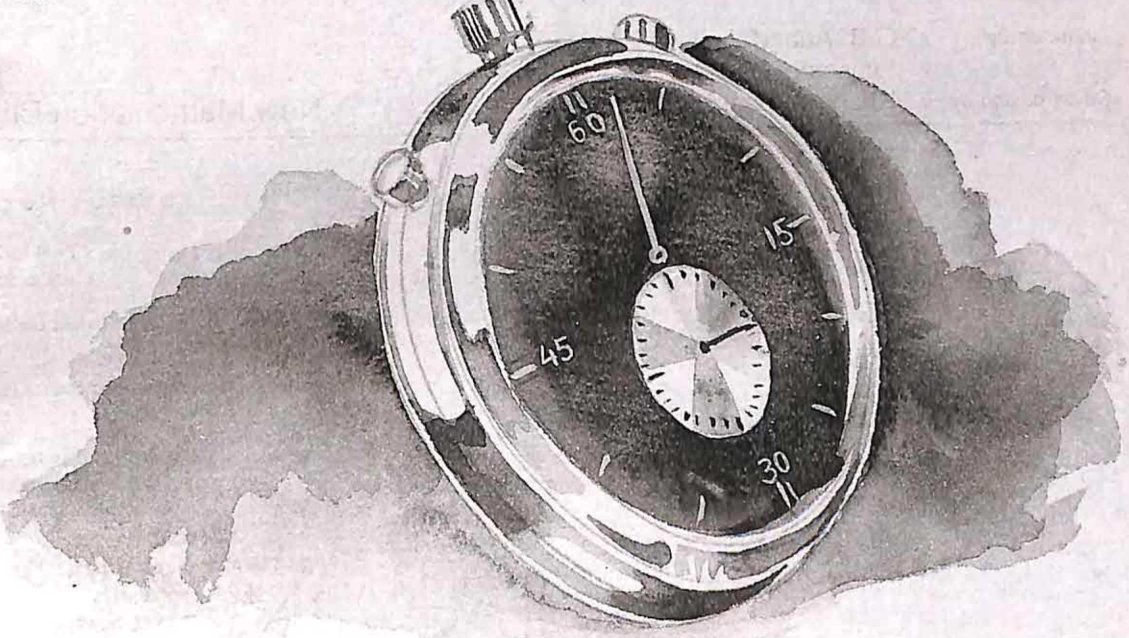

Orient Longman

To the teacher

New Matriculation Physics is a series of five books developed for class 6-10 of the Tamil Nadu Matriculation system. It closely follows the new enriched Matriculation syllabus.

One of the main features of the new syllabus is that activity and observation are given a very important place in understanding science. Every effort has been made to unfold the scope and purpose of the syllabus. This series departs from the conventional and emphasises a practical, 'discovery' and 'learning by doing' approach.

The subject matter to be studied has been carefully arranged keeping in mind the age level and psychology of the child. No effort has been spared to support the text with clear, labelled illustrations. The language has been kept simple and direct to enable the students to read the text themselves.

Several activities and projects have been suggested, wherever possible, within the scope of the lesson. Most of these need simple improvising or inexpensive materials.

The exercises for each chapter are exhaustive and include questions based on comprehension and application of basic principles rather than on mere recall.

It has been the concern of the authors that children are encouraged to discover for themselves the pleasure of learning about the fascinating 'laws of nature'.

The author

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New Matriculation Physics 8

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MATRICULATION SYLLABUS FOR STANDARD VIII - PHYSICS

S.No	*Concept/Theme*	*Expected outcome of learning*	*Teaching/Learning activities*
STANDARD VIII			
1.	**Measurement**		
1.1	Small lengths	Develops skill in the use of the vernier scale.	Measures objects using a vernier scale in vernier callipers.
1.2	Estimation	Develops skill in estimation, and the ability to choose the appropriate measuring device for the need.	Estimates and roughly measures the height of a tree or building. Lists out the steps involved in using a beam balance.
1.3	Mass	Recognises the various parts of a physical balance, and their functions.	
2	**Mechanics**		
2.1	Speed, velocity and acceleration	Differentiates between speed, velocity and acceleration.	Plots distance-time graphs. Reads and interprets them.
2.2	Scalars and vectors	Differentiates between scalars and vectors.	Lists out common scalar and vector quantities.
2.3	Forces	Identifies the factors involved when a force acts on a body.	Learns graphical representation of a force.
2.4	Combination of forces acting at a point	Identifies the resultant force.	Numerical examples of algebraic addition of forces.
2.5	Inertia - of rest - of motion	Differentiates between inertia and motion.	Lists examples from every day life of inertia, rest and motion. Conducts simple experiments to illustrate inertia.
2.6	Centre of gravity		Locates the c.g. of regular and irregular lamina.
2.7	States of equilibrium	Distinguishes between states of equilibrium.	Learns to use a plumb line. Finds out the factors which affect the stability of a body.
2.8	Simple machines : Mechanical advantage, velocity ratio and efficiency Lever system and block and tackle	Sees relationship between the component of a simple machine. Calculates M A of simple machines.	Identifies the state of equilibrium of a body by observing its position. Makes some c.g. toys.
3	**Hydrostatics**		
3.1	Density and relavitve density	Differentiates between density and relative density.	Learns the use of an r.d bottle to find the density of a liquid. Simple numerical problems on relative density.
3.2	Thrust and pressure	Sees the relationship between thrust and pressure.	Lists out examples where pressure is increased or reduced by changing the area. Simple numerical problems involving the relationship between thrust and pressure.

S.No	Concept/Theme	Expected outcome of learning	Teaching/Learning activities
3.3	Fluid pressure - liquid seeks its level - transmission of pressure	Infers that liquid seeks its own level. Recognises the principle of the Bramah press.	Observes the water level and artesian well. Observes the hydraulic brake, hydraulic lift and oil press.
3.4	Archimedes principle	Analyses the application of the principle in life situations.	Verifies the principle. Experiments to study the principle involved, when a body sinks or floats-model of a Cartesian diver. Simple numerical problems based on Archimede's principle to find the volume, given loss of weight in water.
3.5	Atmospheric pressure - measurement	Recognises different types of barometers.	Observes the aneroid and Fortin's barometers, and barograph. Constructs a simple barometer.
	Pumps compressed air	Analyses the making of pumps.	Opens out and studies the parts of cycle, football and exhaust pump. Uses of compressed air.
4	**Heat**		
4.1	Apparent expansion of a liquid	Discriminates between real and apparent expansion.	Experiments to see the difference.
4.2	Curious behaviour of water	Analyses the important role of the property of water in nature.	Experiments to observe the strange behaviour of water. Lists out the several advantages of this property.
4.3	Heat and internal enery		
4.4	Measurement of heat - unit of heat - specific heat	Realises the need for a different type of measurement as compare to length, temperature, etc.	Experiments to observe the factors on which heat energy depends. Compares the specific heat of liquids. Does simple problems on calculation of heat lost or gained.
4.5	Change of state	Appreciates the cycle of energy changes.	Differentiates between evaporation and boiling. Finds the melting point of wax using the capillary tube and cooling-curve methods.
4.6	Temperature control	Recognises the use of thermostats.	Studies the types and functions of a thermostat. Verifies the laws.
5	**Light**		
5.1	Reflection in plane mirrors	Analyses reflection in plane mirrors.	
5.2	Uses of plane mirrors periscope and kaleidoscope	Understands the principle of multiple images in mirrors. Makes models of periscope and keleidoscope. Lists the common uses of plane mirrors.	Experiments and observes single and multiple images.

S.No	*Concept/Theme*	*Expected outcome of learning*	*Teaching/Learning activities*
5.3	Curved mirrors	Distinguishes between concave and convex and real and virtual images. Applies geometrical principles in drawing the formation of images.	Observes different types of curved mirrors. Defines the terms used in connection with mirrors. Draws ray diagrams.
5.4	Uses of curved mirrors	Recognises the use of curved mirrors around him.	Observes the advantage of curved mirrors over plane mirrors in certain situations, for example a rear-view mirror.
5.5	Refraction	Analyses the laws of refraction.	Verifies the laws of refraction. Observes and understands the effects of refraction.
5.6	Lenses	Analyses diagrams of formation of images in lenses.	Draws ray diagrams.
5.7	Uses of lenses	Recognises uses of lenses in life.	Lists the use of lenses and observes how they are used in optical instruments.
6.	**Sound**		
6.1	Wave motion - transverse and longitudinal	Differentiates types of wave motion.	Observes transverse and longitudinal wave forms by simple experiments.
6.2	Reflection of a sound	Recognises factors causing echoes.	Demonstrates reflection of sound from different surfaces and positions. Lists some good reflectors and good absorbers of sound. Studies the uses of echoes.
6.3	Musical instruments	Distinguishes between the four basic types of musical instruments.	Lists various instruments in each group, and observes how they are used to produce different kinds of sound.
6.4	Noise	Realises the hazards of noise, and the need to minimise noise.	Lists common sources of sound in the neighbourhood and ways of reducing noise.
7	**Magnetism**		
7.1	Magnetic field	Recognises the influence of a magnet.	Traces the magnetic field around a magnet, or a pair of magnets using a magnetic compass.
7.2	Molecular theory magnetism	Analyses the molecular theory of magnetism.	Experiments and observes the changes in molecular alignment after magnetisation.

S.No	*Concept/Theme*	*Expected outcome of learning*	*Teaching/Learning activities*
7.3	Magnetic behaviour of the earth	Infers the reason behind the directive property.	Learns the use of magnetic compass in direction finding. Make model of magnetic compass.
8	**Static Electricity**		
8.1	Types of charges - positive and negative	Classifies electric charges.	Demostrates how charges are produced on different bodies by rubbing and attraction and repulsion between charged bodies.
8.2	Theory of electrification	Analyses the theory of electrification.	Make a model of simple electroscope to detect charges.
8.3	Conductors and insulators	Discriminates between insultators and conductors.	Lists out examples of conductors and insultors.
9	**Electricity**		
9.1	Structure of the atom	Infers that the cause of electric charge is electron movement.	Models of atoms. Models of circuit on an analogy of a water cycle.. Studies the factors which account for the movement of electrons.
9.2	Develops a simple circuit as path of an electric current.	Develops a simple circuit as path of an electric current.	Observes everyday appliances to see the conversion of electricity to heat and light. Passes a current through an electrolyte and observes.
9.3	Effects of current -- heating and lighting -- chemical -- magnetic	Analyses the effect of electric current in daily life situations. Analyses Ampere's and Maxwell's rules.	Experiments and observes and' verifies the rules.
9.4	Basic idea of electrical discharge of electricity through a gas	Infers that a gas, normally a poor conductor can be made to conduct electricity under special conditions.	

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1. More about measurement

Measurement - small lengths - use of vernier scale and vernier callipers - estimation - mass - physical balance

1. Measuring small lengths

ACCURACY

Suppose you are measuring the height of a bottle in your mother's kitchen. You say it is 18cm. What does that mean? To a physicist, it means that the bottle is not 17 cm or 19 cm, but that its height is between 17.5 cm and 18.5 cm. That amount of accuracy is enough if you are just trying to see if the bottle will fit in a kitchen shelf 19 cm high. But it would not be enough if you are making the legs of a chair. If one leg is 30 .1 cm, another 29.8 cm, a third 30.2 cm and the fourth leg 29.5 cm the difference would be large enough to give you a bad 'rocking' chair!

We realise that the amount of accuracy needed for different purposes varies. We call this the *degree of accuracy.* Whether we are measuring length, volume, time, mass, heat, pressure, current or any other such physical quantity, we require different degrees of accuracy according to the purpose of measurement. When you are buying 500 gm of sugar it does not matter if it is 15 gm or 20 gm less or more than 500 gm. But if you were buying 10 gm of gold it would matter! Again you might not be punished for being one minute late for school. The degree of accuracy in measuring time in some cases can vary by a few minutes without any undue risk of punishment. But think of the degree of accuracy needed for timing the 100 metre race at the Olympics. (Find out the present Olympic record for the 100 metres race !)

You will notice that to describe something more accurately it is necessary to give further decimal places.

18.5 cm means it is between 18.45 cm and 18.55 cm.

18.55 cm means it is between 18.545 cm and 18.555 cm.

18.555 cm means it is between 18.5545 cm and 18.5555 cm.

Similarly 18.0 cm means that the length lies between 17.95 cm and 18.05 cm

THE PRINCIPLE OF THE VERNIER SCALE

Observe the measuring scale in your geometrical instrument box. What is the smallest length you can measure with it ? You will find, it is one tenth of a centimetre or one millimetre. You cannot measure any length smaller than one millimetre with your scale. We therefore say that the *least count* of your scale is one mm. *The smallest* *measure which can be taken accurately with the use of an instrument is termed its least count.*

With your scale, therefore, you cannot get the second decimal position when you are measuring the length of an object in centimetres. So how do we measure an object's length or thickness, etc. upto the fraction of a millimetre ?

The answer to this was put forward by a French Mathematician, Pierre Vernier (1580-1637). He used a second scale along with the main scale. The supplementary scale is called the vernier scale after him. This scale is used along with the main scale to correctly obtain the second decimal place of the centimetre or the inch.

The simplest form of the vernier is a small vernier scale which can slide along a main centimetre or inch scale. The vernier scale is marked in such a way that 'n' divisions of the vernier scale coincides with n − 1 divisions of the mainscale. The common and convenient ratio used is where 10 divisions of the vernier are equal to 9 divisions of the main scale (9 mm if the main scale is in centimetres) see Fig. 1.1.

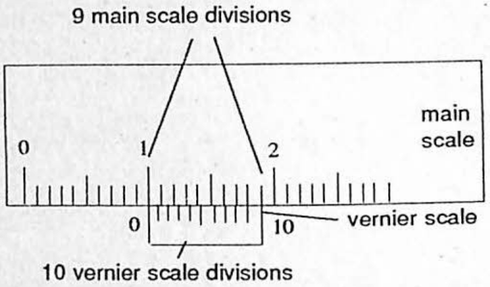


Fig. 1.1 Using a vernier scale

The difference between one main scale division (MSD) and one vernier scale division (VSD) gives us the least count.

In the present case we find that:
10 VSD = 9 MSD
i.e. 1 VSD = 9/10 MSD
Now, we know that the value of one MSD is equal to 1 mm.
Therefore 1 VSD = 9/10 mm
and the least count L.C. = 1 main scale division − 1 vernier scale division (1 MSD − 1 VSD)
= 1 mm − 9/10 mm
that is equal to 1/10 mm = 0.1 mm = 0.01 cm.

Activity 1 : *Observe the protractor in your box of geometrical instruments. You use it to measure angles in your geometry class. What is the smallest angle that can be measured with a protractor? Can you make a curved vernier scale to be used along with the main scale of your protractor? Take your teacher's help. Find out the smallest measure of the angle you can make with your device.*

To use the vernier you have to follow the steps outlined below:

i. See how much the object measures on the main scale. For this, take the reading of the main scale upto the 0 division of the vernier. Let this reading be (*a*) . The main scale reading corresponds to that division on the main scale which has not crossed the 0 of the vernier scale.

ii. See which division on the vernier scale coincides with any of the main scale divisions. Note the number of that division on the vernier scale. If you multiply that number by the least count, you get the actual reading on the vernier scale.

iii. Add the vernier scale reading to the main scale reading to get the final results.

If you look at the diagram on the next page (Fig.1.2) the main scale reading upto the 0 division of the vernier is 3.8 cm i.e., the main scale reading is 3.8 cm. Now, we find that the vernier division that just coincides with a main scale division is the 4th one. Multiplying 4 by the least count (0.01), we get the reading on the vernier scale — [4 x 0.01] = 0.04 cm.

Adding the vernier scale reading to the main scale reading we can get the final result — 3.8 + 0.04 = 3.84 cm.

To make the principle by which the vernier works clear, let us look once more at Fig.1.2. Here the reading shown by the combination of the main scale and vernier is 3.8 cm. Let us see once more how this reading is obtained.

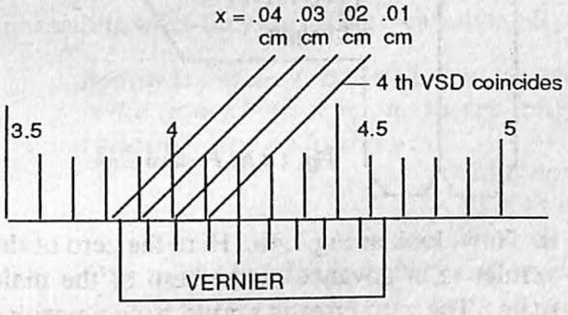


Fig. 1.2

First we note that the main scale reading upto the 0 of the vernier is 3.8 cm. We see that the 0 of the vernier does not coincide exactly with 3.8 cm but actually shows slightly more than 3.8 cm. To know exactly how much more than 3.8 cm and less than 3.9 the reading is, we note, the number of the vernier division that just coincides with any of the main scale division. We see that the 4th vernier division coincides with a main scale division. Now, count downwards from this mark. You will see that the distance between successive main scale divisions and vernier scale divisions increases by 0.01cm. Thus the distance between the zero of the vernier and the main scale division (3.8 cm) before it, is 0.04 cm. This is the vernier scale reading. Adding that to the main scale reading we get the total reading 3.8 + 0.04 = 3.84 cm.

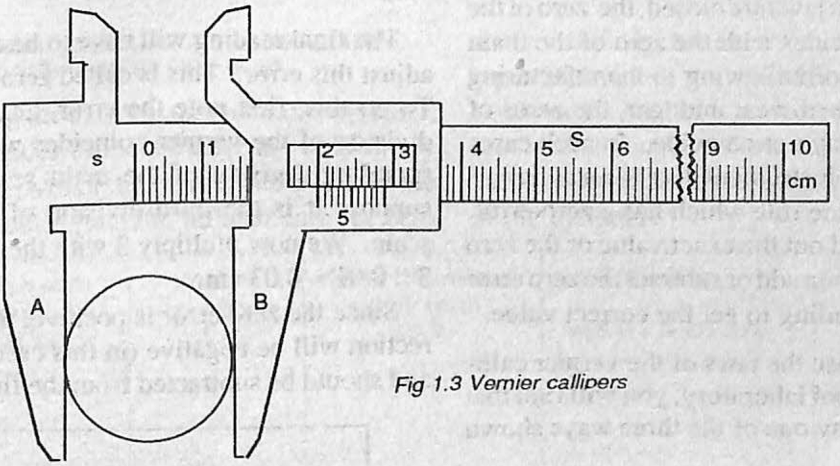


Fig 1.3 Vernier callipers

VERNIER CALLIPERS

The vernier callipers is a simple instrument for measuring small lengths accurately. It makes use of the principle of the vernier. It is also known as slide rule or slide callipers.

It consists of a thin steel bar *S* having main scale divisions on it and with a fixed jaw *A* at one end. A scale with vernier divisions is attached to this steel bar. This has a moveable jaw *B* on the inside. This arrangement can slide along the main steel bar *S*. When the two jaws are brought together or closed, the zero of the main scale should coincide with the zero of the vernier scale. The sliding attachment with the vernier scale on it also bears a screw which can be tightened to fix the vernier scale at any point on the main scale. The screw is used so that the vernier does not accidentally shift while taking the reading.

Usually the main scale is graduated in centimetres on one edge and inches on the other

ESTIMATIONS

You are already familiar with the word *estimate*. Without actually using the word you may have often estimated various things. For instance if you plan to go for a film with your friends, you would roughly have an idea of the minimum amount of money you would need for it (say seven rupees for the movie hall tickets and your bus fare). You also know that, even if you were to have an ice cream, you would not spend more than ten rupees. So, you estimate that you would need about ten rupees to go to the film. You may also, at some time, have tried to estimate the approximate distance from home to your school.

Scientists are good at making estimates. An estimate may only be a quick rough guess, but that does not make it wrong. Suppose the door to your room is one metre wide, and you want to know if a spare table can be brought into your room. A rough estimate that the table is 80 cm wide is quite sufficient for your purpose. It may be only 75 cm wide or in fact 85 cm wide. But it would still pass through the door.

You notice that every estimate has an upper and lower limit — 'it cannot be more than this much and it cannot be less than this much'. It is somewhere in between.

Rough estimates also help us to avoid careless mistakes in our calculations. Suppose a man is trying to find out the area of a wooden board. He finds that its length is 11.9 cm and its breadth is 8.7 cm. He multiplies the two and writes down the area as 985.3 cm^2. If we make a quick estimate we find he is wrong. We know that the length is about 10 cm and the breadth also about 10 cm. We take their product and estimate that the area must be somewhere close to 100 cm^2. 985.3 cm^2 is too far away from our estimate of the area. We are now in a position to see that the man must have put the decimal point in the wrong place. The correct answer we know must be 98.53 cm^2.

Making estimates may seem difficult at first. But you will find that it becomes easier with a little practice. Making estimates can soon become quite amusing.

If you want to estimate the number of leaves on a small tree outside your class room, at first you would say you have no idea. Let us see — how many main branches does the trunk of the tree have? Say, three. How many smaller branches does each of these big branches have ? May be about four or five on an average. It is easy to guess the average number of leaves one of these smaller branches has. Now you can work backwards. You will soon be able to say something like 'that tree has more than thousand leaves but not more than two thousand'. Depending on the circumstances, that would be a good estimate.

Activity 3: *Can you estimate the number of students in your school ? Or the number of words in this book ? Remember, making good estimates is good science.*

Activity 4: *Estimate the height of your class room. It may help if you start by thinking of the height of an eighth standard student. Could one student stand on the shoulders of another and still be upright ? Could more students stand on each other's shoulders ? Give your answer in metres.*

1.3 Mass

Even as a child you would have noticed that unless a thing like a book or a ball is held up, it will fall to the ground. We explain this by the force due to *gravity*, or the force with which the earth attracts all bodies on or near it. You will learn more about gravity later. The force that the earth exerts on bodies can be measured. It is usually represented by the letter *g*. The value of *g* depends on the distance between the body and the centre of the earth. So you can see that the force with which the earth attracts a body will be more at sea level than on high mountains and also more at the poles than at the equator. Scientists speak about the *force* due to *gravity* acting on a body as its weight.

In Class 6 you learnt how to use a spring balance. This is used to find the weight of bodies. If you are weighing a book on a spring balance it will show more weight if it is weighed in Antarctica than if it is weighed in Madras. But observe the balance for weighing used in the provision store near your house which usually has two pans. The object to be weighed is put in one pan and the necessary weights in the other till the two pans are balanced. In such a balance the reading will not change whether you take it to the poles or the moon because the attraction due to gravity acts equally on both the pans of the balance.

We now know that the weight of a body changes depending on where it is. It will weigh more at the poles than at the equator. Also, on the moon a body will weigh only one sixth of its weight on earth because the gravitational pull on the moon is only one sixth that of the earth. But, whether you weigh a given body on earth or on the moon, it will contain the same amount of matter. *The amount of matter in a body is its mass.* The mass of a body will be the same wherever it is measured, *though its weight will* change depending on external forces like gravity. Mass is measured in kilograms.

You will learn more about weight when you are studying about gravity. We shall now see how the amount of matter in a body is measured accurately. In other words we shall see how we can measure the mass of a body accurately.

When you buy sugar or rice the shopkeeper weighs it in kilograms and grams. The smallest weight he can measure on his balance will be 25 or 10 grams. But when more costly things like gold or silver are weighed, you need even smaller weights. Scientists, too, need to weigh very small masses accurately. For this, smaller units of mass like the milligram are used. You know that 1000 grams make a kilogram. One milligram is 1/1000 th of a gram.

1000 gm = 1 kg ; 1 gm = 1/1000kg = 0.001 kg.
1000 mg = 1 gm; 1mg = 1/1000 gm = 0.001 gm
1000000 mg = 1 kg ; 1 mg = 1/1000 x 1000 kg
= 0.000 001 kg = 10^{-6} kg.

We can measure mass accurately upto milligrams using a physical balance.

THE PHYSICAL BALANCE

Observe the physical balance in your school laboratory. It is a very sensitive balance with which we can measure very small masses. You

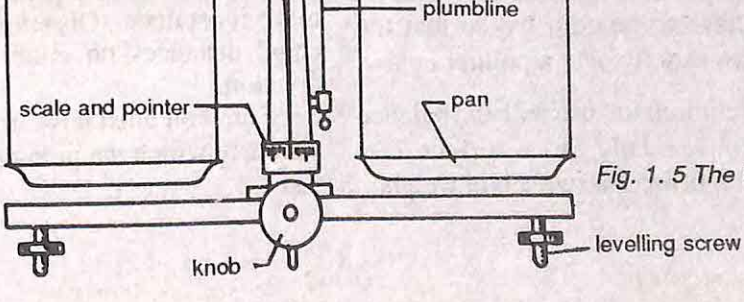


Fig. 1. 5 The Physical Balance

edge. The sliding piece is marked with the vernier corresponding to each of the main scales. That is, the centimetre scale is divided into millimetres and 10 divisions of the vernier scale is equal to 9 divisions of the main scale. So the least count would be .01cm.

If you need to measure the external diameter of any object, say, a cylinder, place it between the jaws of the callipers and adjust the moveable jaw till the cylinder is held firmly between the two jaws. Tighten the screw on the vernier scale. Note the main scale reading upto the zero of the vernier scale. Now note the number of the vernier scale division that just coincides with any main scale division and multiply it by the least count. When you add this to the main scale reading you get the diameter of the cylinder.

Zero error: The vernier is marked in such a way that when the two jaws are closed, the zero of the vernier just coincides with the zero of the main scale. But very often, owing to manufacturing errors or because of wear and tear, the zeros of the two scales may not coincide. In such cases we say that the instrument has a *zero error*. When using a slide rule which has a zero error, we must first find out the exact value of the zero error. We must then add or subtract the zero error with the final reading to get the correct value.

When you close the jaws of the vernier callipers in your school laboratory, you will find that it coincides in any one of the three ways shown below:

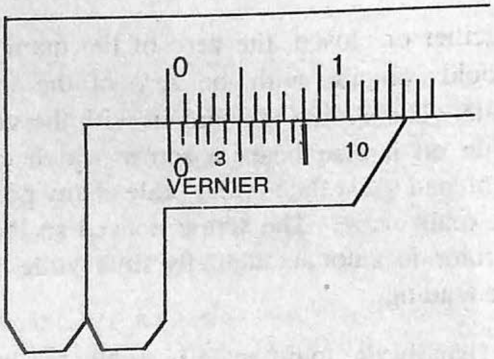


Fig. 1.4 (a) No zero error

i. Look at Fig.1.4a. Does the zero of the main scale and the zero of the vernier scale in the callipers in your school laboratory coincide perfectly as shown in the figure ? If they do, the instrument is perfect and has no zero error.

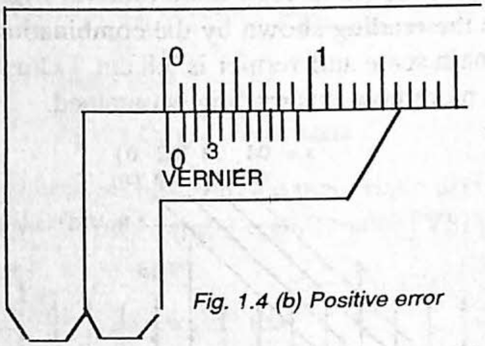


Fig. 1.4 (b) Positive error

ii. Now, look at Fig.1.4b. Here the zero of the vernier is in advance of the zero of the main scale. The zero error is said to have a positive value.

The final reading will have to be corrected to adjust this error. This is called zero correction. To do this, first note the error, i.e., see which division of the vernier coincides with a corresponding division of the main scale. Let us suppose it is the third division of the vernier scale. We now multiply 3 with the least count, 3 x 0.01 = 0.03 cm.

Since the zero error is positive, the zero correction will be negative (in this case—0.03cm) and should be subtracted from the final reading.

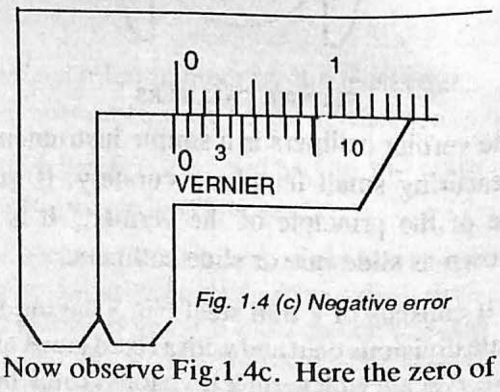


Fig. 1.4 (c) Negative error

iii. Now observe Fig.1.4c. Here the zero of the vernier scale is before the zero of the main scale. The error is said to be negative. In this case, if the 3rd division of the vernier coincides with a corresponding division of the main scale, then the zero of the vernier is behind the main scale by $10-3$ or 7 divisions of the vernier scale. To correct this error, 7 is multiplied by the least count (.01) – $7 \times .01 = .07$cm. Since the vernier scale is before the main scale, the zero error is negative in value and therefore the zero correction will be positive and will be added to the final reading.

Averages : Scientists do not like to rely on only one reading when they are taking measurements. They take many readings and then take their average to obtain an accurate result. To do this you add up the values of the different readings and divide it by the total number of readings.

Sometimes you can make a mistake while you are taking one of your readings. In that case the wrong reading would be very different from your other readings. Then you must not use that reading at all.

Activity 2: *Six boys are asked to measure the length of a table using a metre scale (a scale that is one metre long and divided into cm and mm). The readings are as follows :*

63.2 cm, 63.9 cm
63.8 cm, 63.9 cm
36.4 cm, 63.1 cm

One of the readings is very different from the others. Which one ? What do you think the boy did wrong ? Calculate the average value for the length of the table.

MEASUREMENT OF EXTERNAL DIAMETER USING THE VERNIER CALLIPERS

In measuring the external diameter of a cylinder, the curved sides of the cylinder are held firmly between the jaws of the vernier callipers and the reading is taken (making adjustments for zero error whenever necessary). The procedure is repeated holding the cylinder at different positions and the readings are noted. These readings are then tabulated as shown below. The average value of the different readings gives the diameter of the cylinder.

No	Main scale reading M.S.R	Vernier coincidence V.C	Vernier coincidence x Least count V.S.R	Total reading M.S.R + (V.C x L.C)	Final reading (Total reading ± Zero correction)
1					
2					
3					
4					
5					
6					

Mean value =

VOLUMES OF REGULAR BODIES USING VERNIER CALLIPERS

You've learnt how to calculate the volumes of regular bodies if you know their dimensions. You can use the vernier callipers to find the exact dimensions of regular bodies. Suppose you want to find the volume of a match box or an instrument box, you can find their exact length, breadth and height using the vernier callipers, and then apply the formula V = lbh cu cm.

Similarly we know that the volume of a sphere is $\frac{4}{3}\pi r^3$, where r is the radius of the sphere. You can use the vernier callipers to find the diameter of the sphere and from that calculate the radius and hence the volume.

will notice that the physical balance is kept inside a case with glass doors. Why is this done? Let us observe the various parts of a physical balance before using it (Fig.1.5).

The physical balance has a very light aluminium beam. At the middle of the beam is an agate knife edge pointing downwards. When the balance is not in use, the beam rests on a bracket. Below the central agate knife edge of the beam is an agate plate at the end of a vertical rod which can be raised and lowered using a knob at the base of the balance. When the knob is turned, the vertical rod with the agate plate is raised. This lifts the beam from the bracket and brings the balance into action.

At exactly equal distances from the central knife edge are two more agate knife edges, one at each end of the beam. These two knife edges point upwards, and are parallel to the central one. Two stirrups with bits of agate, shaped like inverted Vs ride over the knife edges on either end of the beam. These carry two hooks each. From the top hooks hang two pans. To the centre of the beam is attached a long pointer which points downwards. It moves on a scale divided into ten or twenty equal parts. When not in use the knob can be turned to the left which will lower the vertical rod and the central beam will then come to rest on the bracket. This arrangement prevents unnecessary wearing off of the central agate knife edge by ensuring that it carries loads only when the balance is in use.

The whole balance is mounted on a wooden or metal base. The base can be levelled by adjusting the levelling screw on which it rests. A plumb line is suspended from the bracket on which the central beam rests when the balance is not in use. To ensure that the balance is in level the screw feet have to be adjusted so that the plumb line hangs exactly over a pointer below.

The weights required for use with the balance are arranged conveniently in a weight box (Fig.1.6). The weight box has two sets of weights. One set, made of brass, consists of multiples of a gram. The other set consists of submultiples of a gram, i.e., milligrams, and are called fractional weights. The fractional weights are made of flat strips of metal with raised edges by which they can be picked up using the forceps which is provided with the weight box. (Can you say why should one not handle the weights with one's hands ?). The compartment containing the fractional weights is usually covered with a glass plate to protect the weight from dust and moisture.

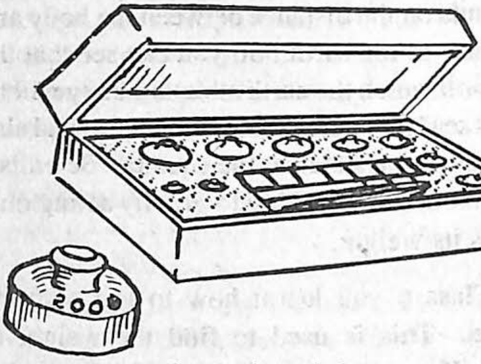


Fig. 1.6 A weight box

The weights are arranged in the following order :

Gram weights : 100 gm, 50 gm, 20 gm, 20 gm, 10 gm, 2 gm, 2 gm, 1 gm.

Fractional weights : 500 mg, 200 mg, 200 mg, 100 mg, 50 mg, 20 mg, 20 mg, 10 mg.

Using the physical balance : To measure the mass of a body accurately using the physical balance, carefully follow the steps given below:

i. Observe if the balance is level. If not, adjust it by working the two screw feet till the plumb line hangs centrally over the index (pointer).

ii.Gently turn the handle (the knob) to the right. If the beam does not oscillate, wave your hand over one of the pans to disturb the air and make it oscillate. Observe if the pointer moves equal distances on either side of the central division.

iii. You must now need to find out the division at which the pointer will finally come to rest.

This may take a lot of time. We therefore find it by noting five consecutive turning points and then calculating the mean as follows:

	Left	Right
	6	14
	6	13
	7	—
Total	19	27
Mean	19/3 = 6.3	27/2 = 13.5

$$\text{The resting point is} = \frac{6.3 + 13.5}{2} = \frac{19.8}{2} = 9.9$$

This is called the zero resting point (a). *The zero resting point of a physical balance is the resting point of the balance when the pans are empty.*

iv. Place the body whose mass has to be found in the *left* pan. (Why should one not interchange the pans ?.) Now add weights to the *right* pan. Try various combinations of weights until the pointer swings nearly equal distances on either side of the zero resting point you found.

v. Calculate the resting point under these conditions by taking 5 consecutive turning points as shown previously. The resting point with the object in the left pan and a weight of, say, 20.48 gm in the right is 10.05 (b).

vi. If the resting point (b) is more than the zero resting point (a), add 10 mg and again find the resting point (c). If the resting point (b) is less than the zero resting point (a), then remove 10mg and again find the resting point (c).

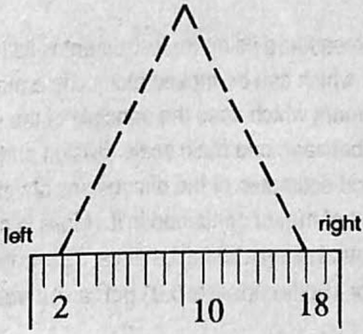


Fig. 1.7 Turning Points

Load in pans		Turning points		Mean of turning points		Resting points	Correct mass of the body gms.
Left	Right	Left	Right	Left	Right		
Nil	Nil	6 6 7	14 13	6.3	13.5	(a) 9.9	
Given body	20.48	8 9	12 11	8.6	11.5	(b) 10.05	20.48
Given body	20.49	4 5 5	13 12	4.6	12.5	(c) 8.5	

The resting point with the object in the left pan and a weight of 20.49 gm in the right is 8.5.

vii. Calculate the correct weights as shown below :

For a difference of 10 mg, the least weight in the box, we have two resting points, 10.05 and 8.5, one on each side of the zero resting point. Of these, the former is nearer to the zero resting point, 9.9. The correct weight of the body is therefore 20.48 gm to the nearest centigram.

viii. *The balance must be arrested while loading or unloading it.*

ix. The weights must be lifted only using the pincers.

x. Add the weights in the descending order of magnitude and place the larger weights in the centre of the pan.

The given table clearly outlines the method of weighing .

Since (b) is closer to (a) than (c) the correct mass of the body is 20.48 gm.

Basic concepts

1. The smallest length that can be measured using an instrument is its least count.
2. A vernier scale is a second scale which can be moved alongside a main scale. The vernier callipers is an instrument which uses the principle of the vernier scale.
3. The least count is the difference between one main scale division and one vernier scale division.
4. It is useful to be able to make good estimates of the dimensions of various objects, distances, etc.
5. The mass of a body is the amount of matter contained in it. Mass is not the same as weight. The weight of a body is usually found using a spring balance. The mass of a body is usually found using a physical balance. The weight of a body correct to 0.01 gm can be weighed using the physical balance.

Some investigatory projects/activities

1. *At three or four o'clock in the afternoon on a sunny day, observe the shadow cast by your school building. At the same time, measure the shadow cast by a half metre scale. Can you estimate the height of your school building using the two values ? (Clue: You have to use the principle of ratios).*
2. *Try and estimate the height of a tree or pole in the same way.*
3. *Make a simple beam balance using a ruler, thick twine and two small plastic cups. Make weights for your balance using small balls of plasticene or modelling clay. Use the beam balance in your school laboratory to make weights of 5, 10 and 20 grams for your balance. Experiment with your beam balance and try to find out the scientific principle on which it is based. (Try and read the second chapter of this book on your own. Write a paragraph on how the beam balance is used based on the principle of levers .)*
4. *Find out what is a weighing bridge. Also, observe and describe various balances you see around you, e.g. the balance in a postoffice for weighing letters and packets. Find out the smallest mass that can be accurately measured on each kind of balance.*

REVISION TIME

1. Choose the corect answer(s).

1. The smallest measurement which can be taken accurately using an instrument, is its ....
   (a) main scale. (b) zero scale. (c) least count.
2. Estimation is ......
   (a) an unscientific rough guess. (b) a rough calculation which is useful to scientists in some cases. (c) is always the best method of measurement.
3. In a physical balance the body to be weighed is placed in the ......
   (a) right pan (b) left pan.
4. The mass of a body ......
   (a) is the same everywhere (b) changes with temperature (c) changes with the place you are weighing it in.
5. Mass and weight are ......
   (a) different words for the same thing. (b) different properties of a body. (c) completely unrelated measurements.

2. Differentiate between the following pairs :

1. main scale and vernier scale.
2. least count and zero error.
3. mass and weight.
4. beam balance and spring balance.
5. averages and estimations.

3. Fill in the blanks.

1. The scale which slides over the main scale is called the ....
2. Usually, in vernier callipers .... main scale divisions are equal to ....
3. In a physical balance, the object to be weighed is placed in the .... pan and the weights are placed in the .... pan.
4. The smallest weight in the weight box of a physical balance is ....
5. The resting point of the pointer of a physical balance when no weights are placed in either pan is called the ....

4. Draw a neat diagram of a physical balance and name its parts.

5. Answer the following briefly :

1. Explain the principle of the vernier scale.
2. What is least count ?
3. What is meant by zero error ?
4. Why do we use averages in measurement ?
5. What is estimation ? Is it scientific ?
6. Why is there a plumb line in a physical balance ?
7. What is zero resting point ? How is it determined.?

8. In a vernier the main scale is divided in mm. The vernier has 20 divisions which are equal to 19 main scale divisions. What is the least count of the vernier ? (Ans: 0.005 cm)
9. The least count of vernier callipers is 0.01 cm. It has positive zero error. The 4th division of vernier coincides with a main scale division. The vernier callipers is used to measure the thickness of a block of steel. The main scale reading is 2.8 cm and the 6th division on the vernier scale coincides with a main scale division. What is the thickness of the steel block ? (Ans: 2.82 cm)
10. In a physical balance, the five successive turning points when the pans were empty were: 6, 14, 7, 13 and 8. Tabulate the left and right turning points and calculate the zero resting point. (Ans: ZRP = 10.25)

6. *Answer the following in detail :*

1. Describe a vernier callipers. How will you use it to measure small lengths ?
2. Describe the common balance. How is it used to find the mass of small objects accurately.

2. Mechanics

Speed - velocity and acceleration - scalars and vectors - forces and combination of forces - inertia of rest and of - motion - centre of gravity - states of equilibrium - simple machines - mechanical advantage - velocity ratio and efficiency - lever systems.

Mechanics is that branch of physics which deals with force and energy and their effect on bodies. When we are dealing with moving bodies and various forces acting on them, we are studying *dynamics* or the science of objects and bodies in motion. The study of the interaction of different forces and its effect on bodies at rest is called *statics*.

When you are lying on your bed you feel that you are at rest but infact you are sharing the motion of the earth round the sun, and also the motion of the whole solar system.

Hence, *rest* and *motion* are relative terms depending on what is observed and the observer. Again, when you are sitting beside someone in a bus, you are stationary (at rest) in relation to each other, but to someone waving at you from the bus stop, you are moving along with the bus away from the person. With respect to the bus you are at rest. But with respect to the person at the bus stop you are in motion. Thus, whether you are in motion or rest depends on whether the stationary person or the bus is your *frame of reference*. Being creatures of the earth we study all instances motion and rest, even that of other planets and stars, in relation to the earth or with the earth as the *frame of reference*.

As a young scientist you will notice that all things around you are either at rest or in motion. We shall now try and understand what keeps things at rest or in motion. Being physicists we shall try and measure various quantities connected with motion and rest.

2.1 Speed, velocity and acceleration

You are familiar with the word *speed*, the speed of a bus, a cyclist, a runner, etc. *Speed is the distance a body moves in one unit of time, or the rate of change of distance for every unit of time*. In the SI system , the unit we use to measure distance is the metre and time is measured in seconds. So, according to our definition, if a cyclist covers hundred metres in 10 seconds, his speed is the distance he can cover in one second i.e., 100/10 = 10 m/s (metres per second).

When we are calculating the speed of a train or a bus it is convenient to measure it in kilometres per hour. You have seen that speed is distance travelled per unit time or

$$\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

It is easy to convert speed measured in km/hr to m/s.

$$1 \text{ km/hr} = \frac{1 \text{ kilometre}}{1 \text{ hour}} = \frac{1000 \text{ metres}}{60 \times 60 \times 60 \text{ seconds}}$$

So, when we say that a bus is travelling at 50km/hr we know that it is travelling at

$$50 \times \frac{1000}{60 \times 60 \times 60} = .23 \text{ m/s (approximately).}$$

VELOCITY

Look at the hands of a clock. Each hand moves with a fixed speed. The minute hand, for example, completes one revolution of the clock in sixty minutes or 60 x 60 = 3600 seconds. We can say that the minute hand moves at a uniform speed, but is it always travelling in the same direction ? To answer this, imagine a small arrow fixed to the tip of the minute hand so that the arrow is perpendicular to the hand. You can draw the face of the clock and show the minute hand with the arrow at its tip at various points of time. What do you notice ? Though the speed of the minute hand remains constant, it is continuously changing the direction of its motion. We then say that the minute hand has constant speed but varying velocity.

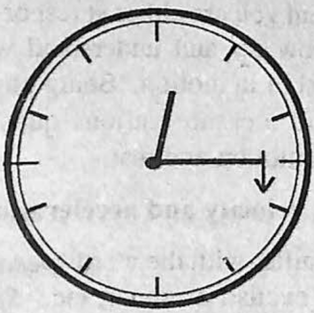


Fig. 2.1

Though *velocity* and *speed* are usually used as if they mean the same thing, we see that there is a difference. Velocity (v) is speed in a particular direction. *Distance covered in a particular direction is called displacement.* Observe Fig. 2.2. From a point X, a man moves 15 km due north and stops at a point Y. Then he moves 15 km due east, to a point Z. Now, the total distance the man has travelled is 30 km but the displacement is only 21.2 km *northeast*. Mark the two words *scalar* and *vector* in brackets. You will deal with them in the next section.

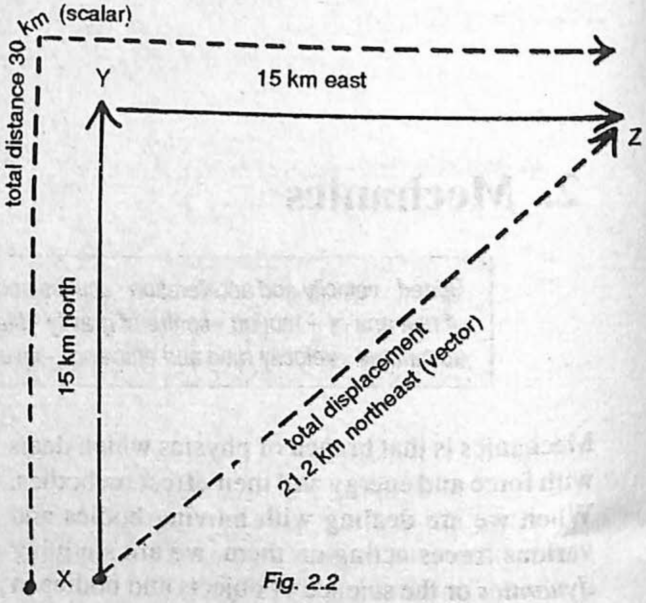

total distance 30 km (scalar)
Y
15 km east
Z
15 km north
total displacement 21.2 km northeast (vector)
X

Fig. 2.2

Now, we can define velocity as *the rate of change of displacement per unit time.*

$$\text{Velocity } (v) = \frac{\text{displacement}}{\text{time}}$$

It is expressed in metres per second (m/s) or centimetres per second (cm/s).

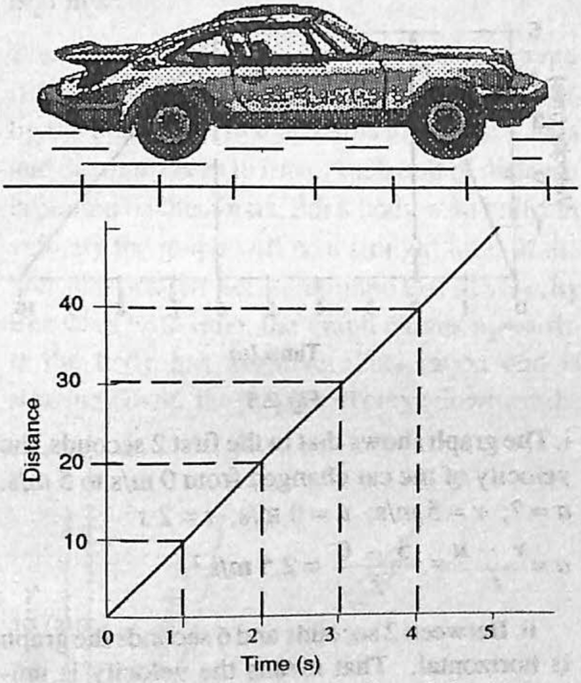
$v = s/t$ or $t = s/v$

When a body is moving in a straight line its speed and velocity are the same. But, when a body is moving with uniform speed in a curved path, the speed and velocity are not the same since the velocity changes with the change in direction. Speed represents only the magnitude of velocity but not its direction.

UNIFORM SPEED AND AVERAGE SPEED

When a body travels equal distances in equal intervals of time and in the same direction, it is said to be moving with *uniform velocity*.

Activity 1: *Take a toy car which runs on batteries and moves at a constant speed on a level surface. Place two rows of books on a level table so that the toy car can run between them from one end of the table to the other without changing its direction. At every ten centimetres along this track put markers to indicate the distance travelled. Now if you start the toy car from the zero distance mark at one end of the table and note the time it takes to cross each of the distance markers, you can plot a graph like that in the figure. If the car travelled with a uniform velocity you will get a straight line on the distance/time graph.*



Can you find out the velocity of the toy car from the graph ?

You know that most things around you that move do not do so with uniform speed or velocity. A bus, for example, starts from rest, slowly picks up speed, then slows down and comes to a stop. In the first one minute the speed of the bus, let us say, increased from 0 km/hr to 25 km/hr. At the end of 5 minutes it has reached a maximum speed of 40 km/hr and then slowed down and came to rest at the end of the 8th minute after it began to move. Let us say that the bus has covered 4 kilometres in the 8 minutes it has moved.

Now, we know that the bus had travelled at different speeds at different periods of time. In this case we can only speak of the average speed (or velocity) of the bus. The average speed of a body moving with variable velocity or speed is given by dividing the total distance covered by the total time taken. In the case above, the average velocity of the bus will be 4 ÷ 8/60 (since 8 minutes is 8/60th part of an hour). That is 4 x 60/8 = 30 km/hr. (Can you convert that to metres per second ?)

ACCELERATION

In your school playground or in your neighbourhood park you may have played on a slide. You know that a slide has steps to take you to the top and then a smooth, slippery surface for you to slide down into a sand pit. If the smooth surface were horizontal it would be like a bed and you would not move at all. If it were vertical you would fall like a stone that is dropped. But slides constructed are at an angle to the ground. You could call the smooth surface down which you slide an *inclined plane* (in your school laboratory you will find inclined planes which are used for experiments about which you will learn in higher classes). Do you remember coming down a slide? You begin slowly and as you slide down you gather more and more speed! In other words you *accelerate* as you come down.

Most things around you that move do not move with uniform velocity. They are usually increasing speed or slowing down. Whenever the velocity of a body changes either by an increase or a decrease in speed (or by a change of direction or when both direction and speed change) it is said to have an acceleration.

Acceleration is the rate of change of velocity with respect to time .

We know that the amount by which a body's velocity has changed is given by the difference between its initial velocity (u), and its final velocity (v). Acceleration therefore is given by the formula :

$$\text{Acceleration} = \frac{\text{final velocity — initial velocity}}{\text{time taken}}$$

or $a = \frac{v-u}{t}$ where u is the initial velocity and v is the final velocity and t is the time taken.

What is the unit of acceleration ? You know $v-u$ will be expressed in metres per second and time in seconds.

$$\frac{m/s}{s} = \frac{m}{s} \times \frac{1}{s} = m/s^2$$

In other words acceleration is expressed in metres per second square or m/s².

When the speed of an object is increasing, it has a positive acceleration in the direction of the motion. When a body is slowing down it has negative acceleration (deceleration or retardation). In other words it has an acceleration which is against the direction of its motion. (Acceleration, therefore has both magnitude and direction.)

Let us consider two examples of acceleration:

i. A Maruti car accelerates steadily or uniformly from 20 m/s to 40 m/s in 10 seconds.

$$\text{Acceleration } (a) = \frac{\text{change in velocity}}{\text{time}}$$

$$\frac{40\ m/s - 20\ m/s}{10\ s} = \frac{20}{10} = 2\ \text{m/s}^2$$

ii. Suppose a cyclist starting from rest, accelerates at 2 m/s² for 4 seconds. What is his final velocity at the end of the 4th second?

$a = 2$ m/s²; $v = ?$ $u = 0$ m (he is starting from rest); $t = 4\ s$.

$$a = \frac{v - u}{t}$$

$$2 = \frac{v - 0}{4}$$

$2 \times 4 = v - 0 \qquad v = 8 m/s$

Look at the graph below. It represents the acceleration of a car.

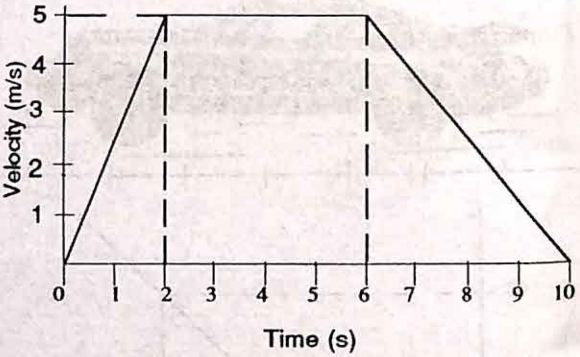


Fig 2.3

i. The graph shows that in the first 2 seconds, the velocity of the car changed from 0 m/s to 5 m/s.

$a = ?$; $v = 5$ m/s; $u = 0$ m/s; $t = 2\ s$

$$a = \frac{v - u}{t} = \frac{5 - 0}{2} = 2.5\ \text{m/s}^2$$

ii. Between 2 seconds and 6 seconds the graph is horizontal. That means the velocity is uniform. What is the value of acceleration here ?

$u = 5$; $v = 5$; $t = 6$; $a = ?$

$$a = \frac{v - u}{t} = \frac{5 - 5}{6} = 0\ m/s^2$$

A body travelling with uniform velocity has zero acceleration.

iii. The last part of the graph shows retardation or deceleration. The velocity decreases from 5 *m/s* to 0 *m/s* in 4 seconds.

$a = ?$; $v = 0\ m/s$; $u = 5\ m/s$; $t = 4\ s$.

$$a = \frac{v - u}{t} = \frac{0 - 5}{4} = -1.25\ \text{m/s}^2$$

Why does the acceleration have a negative value?

Sometimes acceleration is uniform. *Acceleration is said to be uniform when equal changes of velocity take place in equal intervals of time.* For example, let a body have a velocity of 5 m/s at a given time. One second later its velocity is found to be 10 m/s, and one more second later its velocity is found to be 15 m/s and so on. The velocity of the body is found to be uniformly changing by 5 m/s every second. The body in other words has a uniform acceleration of 5 m/s^2.

Time-distance graph : A time-distance graph (Fig. 2.4) is one in which the distance travelled by the body is plotted upwards along the *Y* axis and the time taken to travel each unit of distance is plotted on the *X* axis. For a body with uniform velocity the graph will be a straight line. If the body has positive acceleration so that its velocity increases with time, the graph curves upwards. If the body has negative acceleration and is slowing down, the graph will curve downwards.

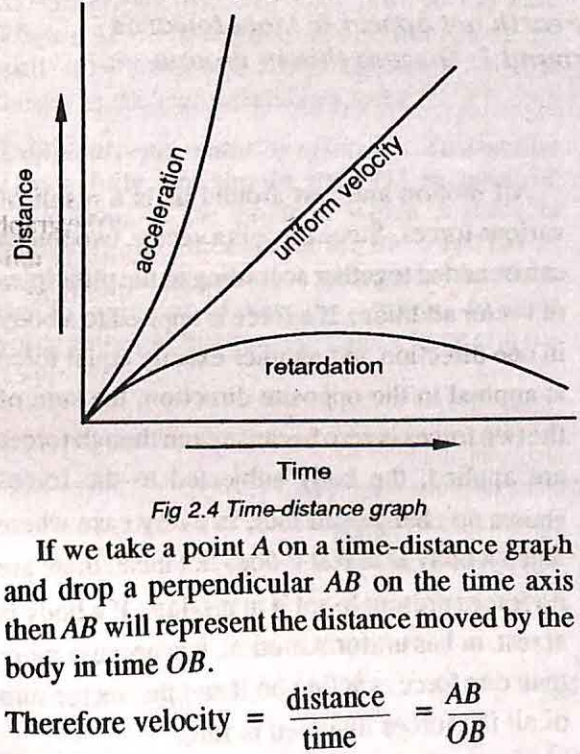


Fig 2.4 Time-distance graph

If we take a point *A* on a time-distance graph and drop a perpendicular *AB* on the time axis then *AB* will represent the distance moved by the body in time *OB*.

$$\text{Therefore velocity} = \frac{\text{distance}}{\text{time}} = \frac{AB}{OB}$$

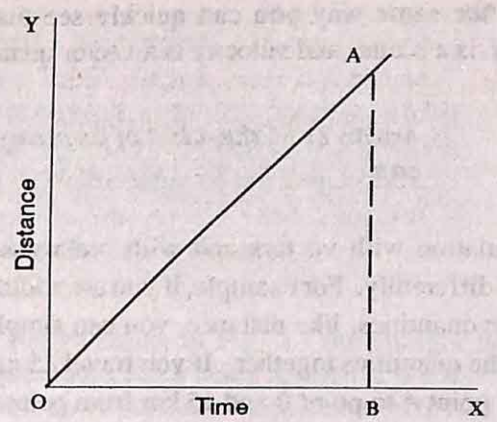


Fig. 2.5

$\frac{AB}{OB}$ is known as the gradient or slope of the line *OA*.

2.2 Scalars and vectors

A quantity that has both magnitude and direction is a vector quantity. A quantity that has magnitude only is a scalar quantity.

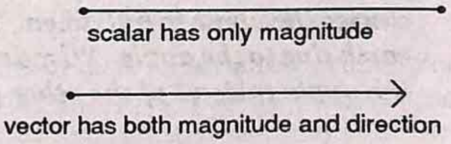

scalar has only magnitude
vector has both magnitude and direction

Fig. 2.6

For example, distance is usually treated as a scalar quantity. A car can be said to have travelled a distance of 15 km in whatever different directions it may have travelled during that 15 kilometres.

In many cases, however, direction does make a difference when it is combined with the magnitude of the distance travelled. If town *A* is 15 km due north of town *B*, then it is not enough to tell a man to travel 15 km from town *A* to reach town *B*. The direction he has to travel must be told. If he travels 15 km due north from town *A* he will reach town *B*. If he travels 15 km in any other direction he will not. We have learnt that the magnitude and direction of travel combined, gives the *displacement*. Displacement is a vector quantity.

In the same way you can quickly see that *speed* is a scalar and velocity is a vector quantity.

Are the following vector or scalar quantities ? mass; weight; time; acceleration.

Activity 2 : *Make a list of as many vector and scalar quantities as you can.*

Calculation with vectors and with scalars are done differently. For example, if you are adding scalar quantities, like distance, you can simply add the quantities together. If you travel 15 km from point *A* to point *B* and 15 km from point *B* back to point *A*, you would have travelled a distance of 30 km (15 km + 15 km). But if you are calculating the displacement which is a vector quantity you will find that though you have travelled a distance of 30 km you are back where you began, or that displacement is 0.

2.3 Force

The word force comes from the Latin word 'strength'. We have all used this word often in everyday activities. But in physics we need to understand it scientifically.

Motion, you know, involves force of one kind or another. It was an Italian astronomer, Galileo Galilei (1565 - 1642), who first tried to understand motion scientifically and mathematically. Later, Sir Issac Newton (1642 - 1727), discovered more facts about bodies in motion and stated the laws of motion.

Activity 3 : *Forces always occur in pairs. If you pull a rope, the rope also pulls you with the same force. The earth pulls an apple and this force causes the apple to fall down. The same force must therefore act on the earth due to the apple. Why does the earth not appear to move towards the apple instead of the other way round ? Discuss this in groups.*

Newton's first law of motion states that *every body remains in its state of rest or uniform motion in a straight line unless an external force acts on it.* We can use this law to define force. Force is that which changes or tends to change a body's state of rest or uniform motion in a straight line.

We know that the application of force may make a stationary body move, increase or decrease the speed of a moving body, make it change its direction of motion (e.g., a batsman square cutting a ball), or make it change its shape (e.g., squeezing a rubber ball).

All motion and rest around us is a result of various forces. Since force is a vector, two forces can be added together according to the principles of vector addition. If a force is applied to a body in one direction and another exactly equal force is applied in the opposite direction, the sum of the two forces is zero because even though forces are applied, the body subjected to the forces shows no change. In fact, in every case where when a body is at rest it does not mean there are no forces present to set it in motion. If a body is at rest, or has uniform motion, it is because more than one force is acting on it and the vector sum of all the forces involved is zero.

Activity 4 : ***Questions to think about :*** *Sometimes a force has no visible effect at all. When you sit on a table, do you exert a force on the table? Does the table move? Does it stretch, or bend? What would happen if the table top were made of a very thin plywood top and you sat on it? Even if you are sitting on a thick table there would be a small dent but this would be very tiny and you would need a special apparatus to see how much you pushed the table down.*

TRANSMISSION OF FORCE

You know there are several kinds of forces. When you throw a ball up you have used force. The ball goes up and then begins to come down because of the force due to *gravity*. A ball rolls along the ground and comes to rest after a time because of a force known as *friction*. When you sit on a cushion it goes down because of *pressure* (which is a force) exerted by your weight on it. When you are pulling a toy cart with the help of a string, the force of pull on the string is known as *tension*.

Hold a stick by one end and with the other end, push a ball. The ball begins to roll. The stick transmitted the force of your push to the ball. When a force is applied at one point and the result of the force works at another point it is known as the *transmission of force*.

Graphical representation of forces : To describe a force fully, we should state (1) its point of application, or the point at which a force is applied, (2) the direction of the force and (3) its magnitude. A straight line with an arrow can be used to represent all these three things. In other words a straight line can represent a force graphically.

For example, in Fig. 2.7 the straight line *A* represents a force being applied at point *O*. We know that the point of application of the force is *O* because the line begins there. The arrow at the end of the line represents its direction. Each unit length of the line represents one unit of the force. The line in the figure is 4 cm long and so represents a force of 4 units.

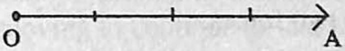


Fig. 2.7

2.4 Combination of forces acting at a point

RESULTANT AND EQUILIBRANT

Let two or more forces act on a body. You can, in such cases, think of one single force which can have the same effect on the body as all the other forces combined together. This single force is called the *resultant* of all the other forces. You can, for example, think of a log with two ropes attached to it. Two boys hold the free ends of each rope. They move forward in different directions. Each boy exerts a force on the log through the rope he holds. The log will move in a third direction (Fig. 2.8).

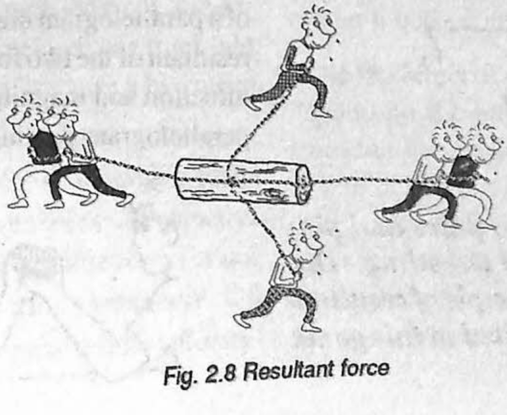


Fig. 2.8 Resultant force

The resultant of the two forces which makes the log move in the third direction can be represented by two boys holding one rope and making the log move in the same direction with the same speed. A force equal in magnitude but opposite in direction to the resultant can bring the log to a stop. Such a force is called the *equilibrant*. The equilibrant of a number of forces acting on a body is that force which when applied along with these forces, keeps the body in equilibrium. Two forces acting together, which produce the same effect as a single force are called the *components* of the single force.

COMBINATION OF FORCES ACTING ON A POINT

i. Resultant of two forces acting in the same straight line : If two forces act along a straight line in the same direction, their resultant is the sum of the two forces.

Similarly, if two forces act along a straight line in opposite directions, their resultant is equal to the difference of the forces and acts in the direction of the greater force. Look at Fig. 2.9. If two forces F_1 and F_2 act in the same direction, their resultant R is equal in magnitude to the sum of F_1 and F_2. If F_1 and F_2 act in opposite directions then their resultant is the difference between F_1 and F_2 and acts in the direction of the greater force F_1.

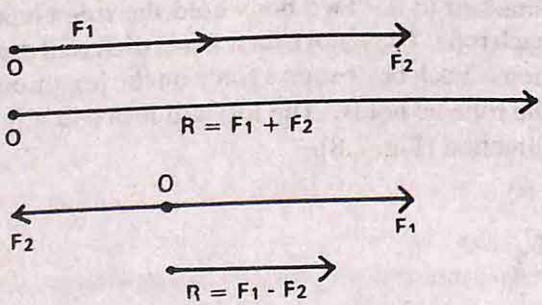


Fig 2.9

ii. Parallelogram of forces : If two forces are not acting in the same straight line but are at an angle to each other how can you add the two forces and find a resultant force? This can be done by vector addition using the help of geometric constructions.

Let there be two forces X and Y acting on point A at an angle to each other. The two forces can then be represented by two lines with arrows indicating their direction. The lengths of the two lines are proportional to the respective forces. (If the magnitude of one force is twice that of the other, then the line representing it is twice as long as the other line.)

If the two lines are now made the sides of a parallelogram $ABCD$, the resultant force Z is represented by the diagonal AC of the parallelogram i.e., that diagonal which lies between the lines representing the two forces (see Fig. 2.10) in the direction shown.

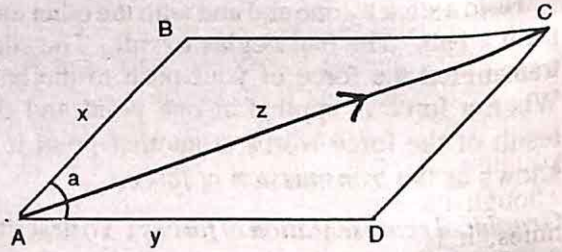
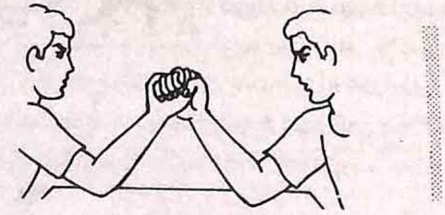


Fig. 2.10 Parallelogram of forces

This is the principle of the parallelogram of forces. If two forces acting at a point are represented in magnitude and direction by two sides of a parallelogram drawn from the point, then the resultant of the two forces will be represented (in direction and magnitude) by the diagonal of the parallelogram passing through that point.

Activity 5 : *Get into pairs and play the game of hand wrestling. Discuss how the principle of resultant forces can be applied in this game.*



MOMENTUM

We saw that one unit of force (one newton) is that quantity of force which can give an acceleration of 1 m/s^2 to a body of mass 1 kg. Now, suppose, you have two marbles, a red one and a blue one. You place the blue marble on a smooth and level floor and slowly roll the red marble from a convenient distance so that it hits the blue marble. As soon as the red marble hits it, the blue marble begins to move. Repeat the experiment by rolling the red marble at various speeds. You will soon realise that the faster you roll the red marble the faster will the blue marble move when it is hit by the red marble.

You can now see that the quantity of force applied by the red marble on the blue will not depend only on the mass of the red marble but also on its velocity.

A football bouncing of the ground and hitting a glass window slowly will not break it. But if someone gives it a hard kick and it travels fast and hits the same window, the glass will break. (This is only an example, not an experiment so you don't have to actually see what happens!). Though the football has the same mass both times, it has a greater *quantity of motion* the second time because it is travelling with a greater velocity.

In an accident a huge truck will cause more damage than a car even if both were moving with the same velocity before the crash. We can explain it by saying that though the truck and car were travelling at the same velocity the truck had a greater *quantity of motion* because it had more mass than the car.

We see that the *quantity of motion* a body possesses depends on both its mass and velocity. In physics, we use the word momentum for the quantity of motion a body has. Momentum of a body is the product of its mass and its velocity.

Momentum = mass x velocity = mv
(kg m/s is the unit of momentum)
Momentum is vector quantity and has the same direction as that of velocity.

(What is the momentum of a car with a mass of 1000 kg when it is at rest? Why?)

2.5. Inertia

If a boy/girl prefers to lie in bed unless someone pushes out him/her, he/she will be called lazy. Matter, too, has a kind of 'laziness' ! All forms of matter are unwilling to change their states unless there is some force 'forcing' it to do so. (Imagine, if there was no force of gravity pulling it down, a ball you throw up would just keep going up and up and up and ..... .) This tendency of all bodies to remain in a state of rest or, if already moving to continue in that motion in a straight line is called *inertia*. You know from Newton's first law of motion, that all bodies have this tendency. (Did you know, the word *inertia* comes from a Latin word meaning 'laziness' !) Therefore, Newton's first law of motion is also known as *the principle of inertia*.

Now, we know that it is harder to push a stationary car and make it roll than it is to roll a bicycle which is at rest. Similarly, we find that different bodies require different amounts of pressure to make them overcome inertia and move. You will find that heavier objects need more force than lighter objects to make them move from rest. So, heavier objects have more inertia or inertia is proportional to the amount of matter a body contains that is, *inertial* mass.

So the effect of a force on a body will not only depend on the magnitude and direction of the force but also on the mass of the body. The magnitude of a force is equal to the product of the mass of the body it acts on and the acceleration it produces in the body. The magnitude of force is expressed in newtons. *One newton is that amount of force which acting on a body of 1 kg*

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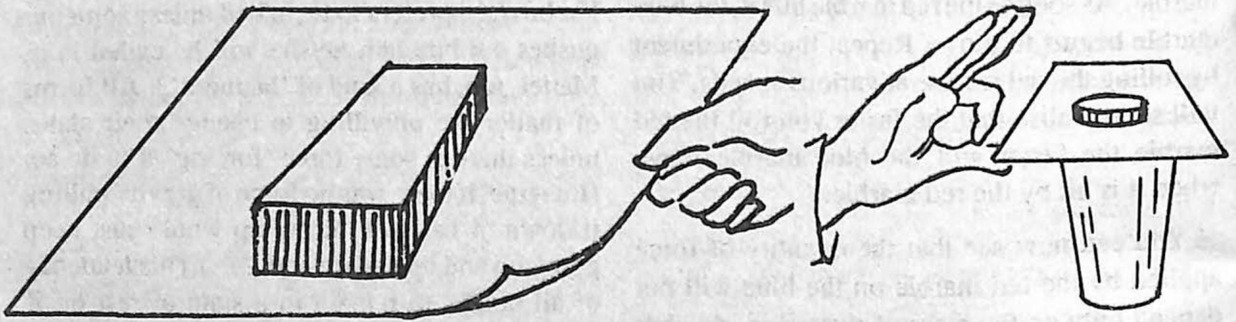
mass produces in it an acceleration of 1 m/s^2.

INERTIA OF REST AND MOTION

From the definition of inertia we have seen that both bodies at rest and bodies in motion have inertia.

Inertia of rest : We know every body continues in its state of rest *unless an external force acts on it.*

Activity 6: *Put a piece of paper under a block of wood. Pull the paper away very fast. What happens to the block of wood ?*



Activity 7: *Place a card over a tumbler and put a 10p coin on it. Flick the card with your finger quickly. What happens to the coin ? Why ?*

The two activities you have just done explains the principle of inertia. When the paper was pulled away from the block of wood, it still remained in place because of inertia. Similarly, when you pushed the card it moved away but the coin continued to stay at rest due to inertia of rest and so dropped into the tumbler.

The principle of inertia of rest explains many facts around us. For example, when you are in a bus and it suddenly moves forward your body jerks backwards. This happens because the lower part of your body which is resting, on the seat or the floor of the bus, moves with the bus while the upper part remains at rest because of inertia and is therefore jolted back.

Inertia of motion : In a bus we saw why one is jerked backwards if the bus moves forward suddenly. Similarly, why do we jerk forward when the driver of a moving bus suddenly applies the brakes ? It is because we were sharing the motion of the bus (moving forward at the same speed as the bus) and when the bus suddenly slows down or stops, our inertia of motion continues to make our body move forward.

Fig 2.11 Inertia of rest

Ideally, a moving body will continue to move in a straight line for ever unless some other force makes it stop. But on the earth, friction, gravity, the resistance of air and other forces make all moving bodies come to a stop unless a new force is brought in to keep it in motion.

Activity 8 : *Think of other examples to illustrate the principle of inertia of motion and rest. Discuss these in pairs.*

2.6 Centre of gravity

Imagine a point (a point has no length, breadth or thickness) which has a mass! Such a point can only move along a line from one point to another. It cannot, for example, spin because there is *nothing* to spin. To make things simple we have been thinking of mass as if it were a point. But actually there are no such points. All bodies have a size and their mass is spread throughout its volume.

But, bodies in some way behave as if their mass was concentrated at some point. The point at which a body's mass *apparently* seems to be concentrated is called its *centre of mass*. When a body has a *symmetrical* shape or has a *regular* shape and has a uniform density then the centre of mass is the geometrical centre of the body.

For example, the earth is essentially a spherical body. Though its density is not uniform, it is most dense at the centre. The earth's centre of mass therefore coincides with its geometrical centre. It is towards this centre that the force of gravity acts or is directed.

Suppose a body is falling towards the earth. Every particle of that body is being pulled by the force of gravity, but the body behaves as if all that force were concentrated at one point within the body. That point is the *centre of gravity* of the body. (Actually , the lower portion of the body, because it is closer to the centre of the earth, is more strongly pulled by gravity. Therefore, the centre of gravity will be very, very slightly below the centre of mass. But the difference is so small we can assume that the centre of mass is the same as the centre of gravity.)

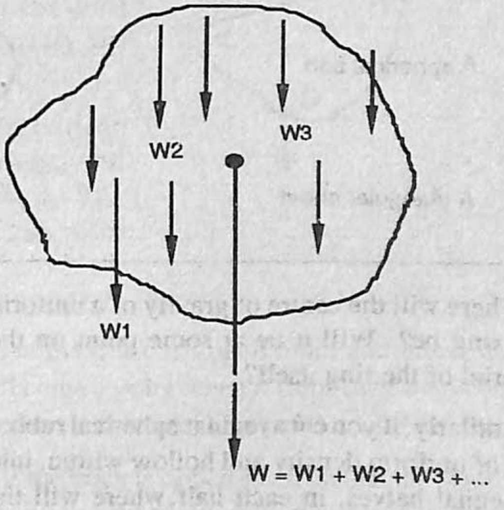


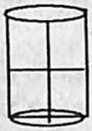
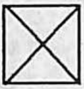
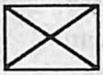
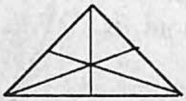
Fig. 2.12 Forces of gravity acting on a body

Consider a body as in Fig. 2.12. We can consider it as being made of many points w_1, w_2, w_3, etc. The mass of the body is distributed along these points. So we see that a number of parallel forces are acting on the body pulling it towards the earth because of the force of gravity. The *resultant* of all these forces is equal to the *weight* of the body acting at a single point *W*. We call this point the centre of gravity of the body.

The centre of gravity of a body (C.G.) is a point where the weight of the body acts.

The centre of gravity of some regular bodies (if they are of uniform density) can be found by locating their geometric centres.

CENTRE OF GRAVITY OF SOME REGULAR BODIES

Regular body		Position of centre of gravity
1. A uniform cylinder or disc		mid - point of axis through centre
2. Rectangular or square plate		intersection of diagonals
3. Rectangular block		intersection of diagonals
4. A spherical bob		centre of the sphere
5. A triangular sheet		point of intersection of medians

Where will the centre of gravity of a uniform iron ring be? Will it be at some point on the material of the ring itself?

Similarly, if you cut a regular spherical rubber ball, of uniform density and hollow within, into two equal halves, in each half where will the centre of gravity lie? Will it be on some point in the material of the ball itself?

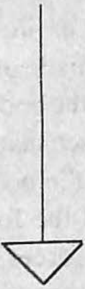


Fig. 2.13 A plumb line

Plumb line : You may have seen this instrument being used if you have watched masons at work. It is used for finding the uprightness of wall, etc. Masons have to use it because if a wall is not perfectly vertical it will lean to a side and be *unstable*, doors and wall-cupboards, etc., would not fit in correctly.

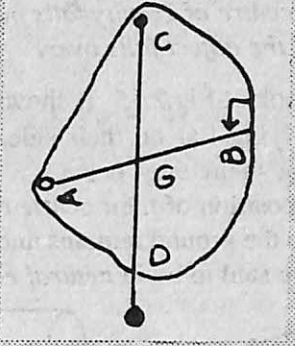
The plumb line consists of a small heavy bob supported by a thread which passes through a hole through the centre of a regular wooden cube. The force of gravity acts vertically down on the bob. So, the cord and bob set themselves when freely held up.

Activity 9 : ***Try and make a plumbline for yourself using a strong tortionless string and a uniform weight. The bob must be heavy or it will move and not be truly vertical. See if you can verify how vertical various things around you are, like the posts of the goal in the football field, your classroom wall, etc.***

FINDING THE CENTRE OF GRAVITY OF AN IRREGULAR LAMINA

Activity 10 : *Take an irregularly shaped lamina like a piece of cardboard. Make three small holes A, B, and C at well-spaced intervals around its edges Clamp a needle on a vertical stand. Now freely suspend the card from the needle by the hole A. The card will come to rest with its centre of gravity vertically below the point of suspension. Suspend a plumbline from the tip of the needle by which the cardboard is suspended. Draw a line on the card along the plumbline. The centre of gravity lies along this line.*

Now repeat the same procedure by suspending the card by holes B and C, respectively, and draw similar lines using the plumbline. The centre of gravity of the card is at the point where the three lines intersect.



2.7 States of equilibrium

The concept of the centre of gravity is useful in considering how stable a body is. Imagine a brick resting on its narrowest base. If it is tipped slightly and then released, it drops back to its original position (Fig. 2.14).

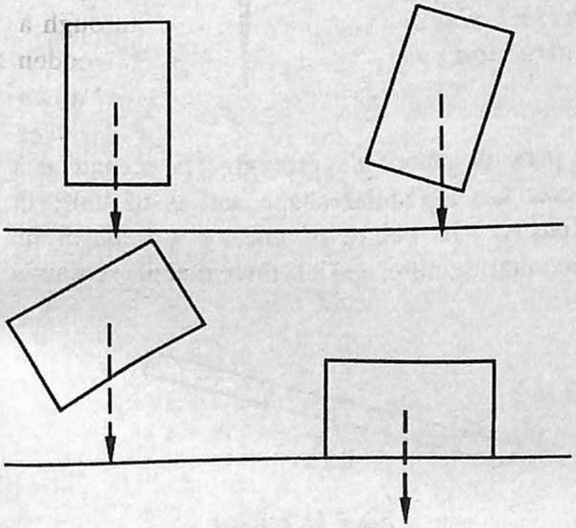


Fig. 2.14 Stable and unstable equilibrium

As the brick is tipped more and more, there will come a point when it flops over onto one of its other bases. (At what point does it fall over?)

If the brick is tipped so much that the centre of gravity is located directly over some point outside the original base the brick falls over. Naturally, the wider the base in comparison with the height, the more force you will have to use to make the body fall over or in other words, the more stable is the body.

i. A *body is said to be in stable equilibrium when on displacing it, the perpendicular from the centre of gravity still falls within the base area and therefore the body comes back to its original position.*

When, for example, a man is carrying a heavy load the perpendicular from his centre of gravity may fall outside the base area formed by the man's legs. He might then fall over. To avoid that he bends forward so that the perpendicular falls within the base area.

Activity 11 : *A funnel which is balanced on its narrow end is in unstable equilibrium. From the above definition of unstable equilibrium, explain why and work out the relationship between its centre of gravity and its base area.*

ii. *An object is said to be in unstable equilibrium if on being displaced the perpendicular from the centre of gravity falls outside the base area and the object falls over.*

iii. Look at Fig.2.15 It shows a cone and a cylinder lying flat on their side surfaces. On displacing them they occupy a new position. But, the position of their centre of gravity with respect to the ground remains unchanged. Such bodies are said to be in *neutral equilibrium*.

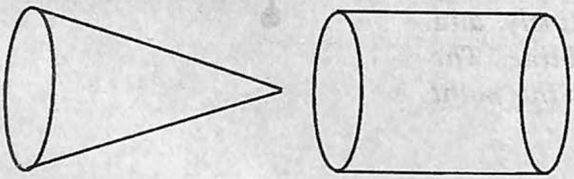


Fig. 2.15 Neutral equilibrium

An object is said to be in neutral equilibrium if on displacement the object occupies a new position and the position of the centre of gravity remains unchanged.

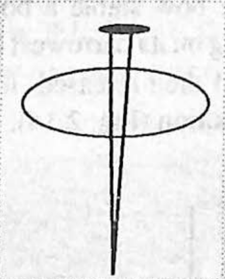
The stabilility of a body or the sort of equilibrium, you now see, depends on the position of its centre of gravity and its base area. By lowering the centre of gravity the stability of a body increases. The stability of a body also increases with the increase of its base area.

2.8 Simple machines

MOMENT OF A FORCE OR ITS TORQUE

If you have played with a top you know that when you set a top spinning you are applying force in such a way as to make the top spin on its pointed and in circles, moving clockwise or anticlockwise.

Activity 12 : *Cut out a small piece of cardboard so that it is in the shape of a regular circle. Pass a pin or nail of convenient size through its centre. The length of the nail is now the line of the axis around which the circular piece of cardboard will spin. You apply a force on your cardboard top by giving a twist to the nail which makes it turn clockwise or anti-clockwise, depending on which direction you gave the quick twist to the nail.*



The tendency of a force to turn an object about an axis or a point is called the moment of force or torque about that axis or point.

MEASURING TORQUE

A *lever* is any rigid object capable of turning about some fixed point called the *fulcrum*. As a practical example you can consider the seesaw in a park or school playground. The seesaw as a lever has a regular shape and is of uniform density. Its centre of gravity will be at its geometric centre, and it is there that the seesaw's

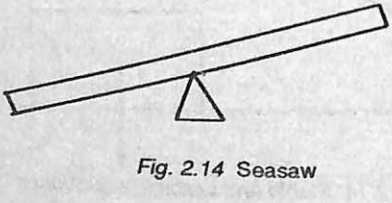


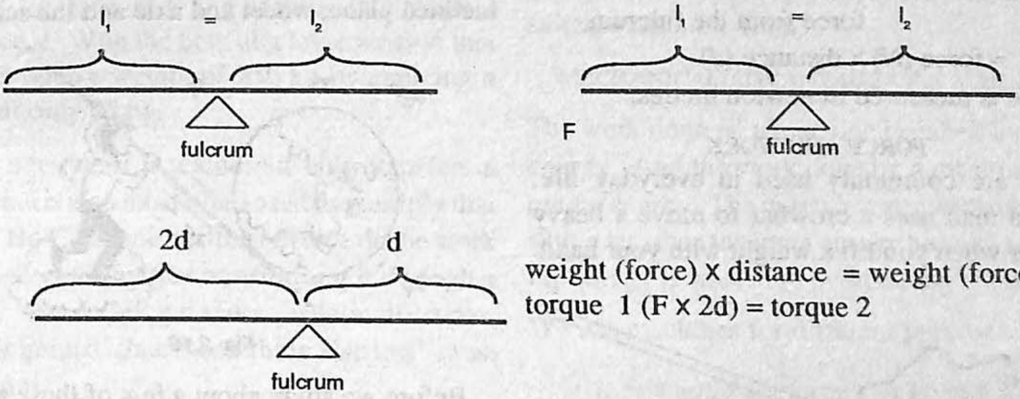
Fig. 2.14 Seasaw

fulcrum is placed (the metal rod about which it turns). This leaves both the sides of the seesaw balanced. (You can use the seesaw to learn and verify the facts about torque and levers and how they work.)

Now, let us consider the board of a seesaw as a *lever* and the iron support at its geometrical centre, around which it swings, as the *fulcrum* and let us say the seesaw is at rest horizontally.

If a downward force is applied to any point on the lever the downward force multiplied by the distance of its point of application from the fulcrum represents a torque, and the lever moves in the direction of the torque.

Let a downward force be applied at the same time to the seesaw lever on the other side of the fulcrum. If the second force is equal to the first and is applied at the same distance from the fulcrum, the two torques are equal in magnitude but not direction (Fig. 2.17). The torque on one side of the fulcrum tends to set up a clockwise rotation; the torque on the other side sets up an equal force of rotation in the other direction, i.e., anti-clockwise. If we represent one torque as t the other must be $-t$. The two torques add upto zero or cancel out, and the lever does not move. It remains balanced.



weight (force) x distance = weight (force)
torque 1 (F x 2d) = torque 2

Fig. 2. 17

On the other hand, if two forces of the same magnitude are exerted on a lever, one acting in the upward direction at one end of the fulcrum and the other acting downward at the other end, then both together produce a motion in the same direction. The two torques then have the same sign (+ve if the direction of motion is clockwise and – ve if anti-clockwise.)

Such a doubled torque is called a couple. (We use the principle of the couple when we wind a clock to spin a top using two fingers.)

From what we have learnt of forces, torques and levers so far, we can say that two equal weights will leave a lever in balance if they are placed on opposite ends of the fulcrum at equal distances from it. This, in fact, is the principle employed in a physical balance. A balance has two pans of equal weight suspended from the ends of a horizontal beam that pivots about a central fulcrum. If an object of unknown weight is placed in one pan, combinations of known weights can be put in the other till the two pans balance. We then know that the unknown mass is equal to the mass of the weights used in the other pan. A lever, having equal and opposite torques, is said to in *equilibrium.*

If two children are playing on a seesaw and both are almost of the same weight, then they will balance each other if they sit at the two ends of the seesaw. But if one child is much heavier than the other, the heavier child must sit closer to the fulcrum for the seesaw to be in equilibrium. This, we know, is because the torque exerted by a weight on a lever depends on the distance of the point where it is applied from the fulcrum. A smaller force applied far away from the fulcrum can exert the same torque as a force applied closer to the fulcrum. From this we can get the following definition and mathematical formula: the moment of force or torque about a turning point is the turning effect of a force. It is equal to the product of the force and the perpendicular distance of the force from the point of rotation or the fulcrum.

Activity 13 : *Use only a seesaw, a measuring tape and a 3 kg weight to find out your approximate weight. Do this activity in pairs.*

torque = force × perpendicular distance of the force from the fulcrum

= force (N) × distance (d)

Torque is measured in newton metres.

FORCE AND WORK

Levers are commonly used in everyday life. When a man uses a crowbar to move a heavy stone or when you lift a weight with your hand.

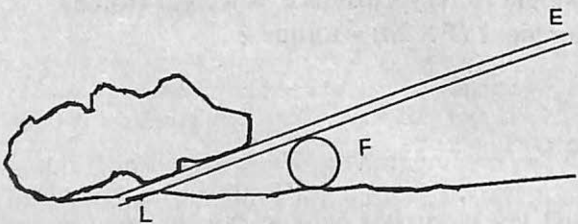


Fig 2.18

Using levers we can do a job using less force. Of course even primitive man used levers (sticks and such things), but it was only during the time of the Greek mathematician Archimedes (287-212 BC) that the principle of its working was understood mathematically. Archimedes knew the ability of levers to multiply forces so well that he could boast, 'Give me a lever long enough and a place to stand and I will move the world!'

Any device that transfers a force from the point where it is applied to another point where it is used, is called a machine.

The lever does this, in such a simple way that you cannot have a simpler machine. It is therefore an example of a simple machine. Other examples of simple machines are the pulley, the inclined plane, wheel and axle and the screw.

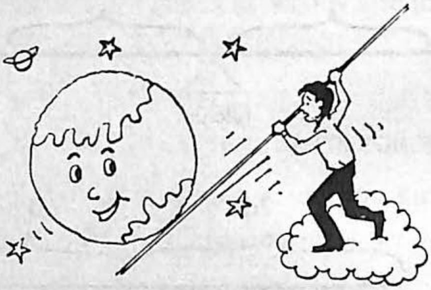


Fig. 2.19

Before we study about a few of these simple machines and what kind of work they do, we must know one important fact about machines. Look at the illustration below (Fig. 2.20).

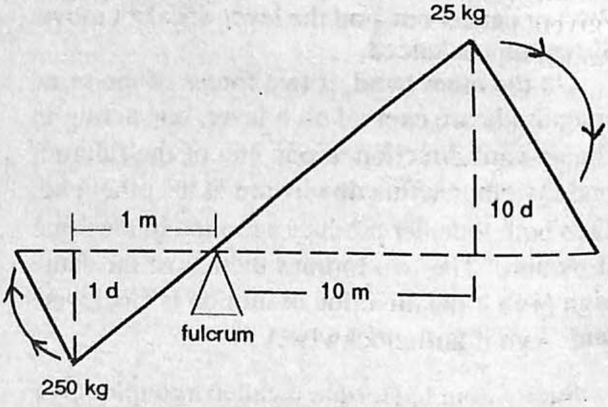


Fig 2.20 Force and distance

The diagram shows a lever with one of its arms one metre long and the other 10 metres long. The shorter arm has a weight of 250 kg placed at its end. The dotted line is the horizontal. We can see that if the short arm with 250 kg weight on it were to become horizontal, it would have moved through a distance *d*.

'If the small arm moves through distance *d*, how much will the long arm move ? Find out from the figure.

From what we learned earlier about torque, we can calculate and find that a force of 25 kg applied at the end of the long arm can make the short arm with 250 kg weight move through the distance *d* by applying only 25 kg of force at the end of the long arm and moving it through a distance *d*. With the help of a lever we find that we can raise a weight of 250 kg by applying a force of only 25 kg.

We see that a machine not only transfers a force, but is also most often used to multiply that force. How can one newton of force do the work of ten newtons by just transmitting it through a lever ? We do not get more for less; if 'something is gained' then 'something else lost' must explain it.

Let us look once again at Fig.2.20 where a 250 kg weight is lifted by using a force equal to only 25 kg of weight. We see that if we apply a force at a point ten times as far from the fulcrum as the weight is, then to lift the weight through a given distance, *we must push the applied force down through ten times that distance*. You may use a smaller force to move a larger force, but you must move the smaller force through a longer distance to make the larger force move through a small distance.

This is true of any machine that seems to multiply a force. The smaller force performs the task that would require a larger force without the machine at the cost of having to move through a correspondingly longer distance. The product of the force exerted and the distance moved in the direction of the force is called the work done. The amount of work done by a force on a body is that force multiplied by the distance through which a body moves in the direction of the force.

$$\text{work } (w) = f \times d.$$

The unit of work is the Joule (J).

When you think about how levers work and how they are used around you, you might think you are doing hard work. Unfortunately, *it involves no action of a force through a distance* and is not 'work' to a physicist, in scientific terms. Then again, standing in one place holding a heavy suitcase seems hard work, but since that suitcase does not move, no work is being done on it ! Is work being done when one lifts the suitcase from the floor?

MECHANICAL ADVANTAGE OF A MACHINE

The work done *on* a machine is called the *input energy*. And the work done by a machine is its *output energy*. The output energy will always be a little less than the input energy because some of the energy is wasted in overcoming friction etc.

We use machines for different purposes :

i. *To multiply a force* : A greater load can be moved by applying a much smaller effort (the jack used to raise a car to change a tyre is an example of such a machine).

ii. *To apply a force in a convenient direction :* The pulley at the top of your school's flag mast does this. When a rope is pulled downwards the flag moves upwards.

iii. *To gain speed* : Using a bicycle you can travel faster than on foot because when you move the pedal through a small distance the wheels move through a much larger distance.

Machines, as we have seen, are made to overcome a greater load by a small effort. In physics, the force which we apply on a machine is the *effort* and the force the machine overcomes is the load. *The ratio of the load overcome to the effort applied is called the mechanical advantage of a machine.*

Mechanical advantage (MA)

$$= \frac{\text{load } L \text{ (newton or kgf)}}{\text{effort } E \text{ (Newton or Kgf)}}$$

If a 25 kgf force is used at one end of a lever to lift a load of 250 kgf at the other end, then the mechanical advantage of the lever would be

$$\text{MA} = \frac{\text{load}}{\text{effort}} = \frac{250}{25} = 10$$

Mechanical advantage being a ratio has no units.

VELOCITY RATIO

Look at the simple machine in the figure . Though you use less effort to raise a greater load, you find that you have to apply that effort over a greater distance. In Fig.2.21 for example, you find that you have to apply the effort through 60 cm in order to raise the load by 30 cm.

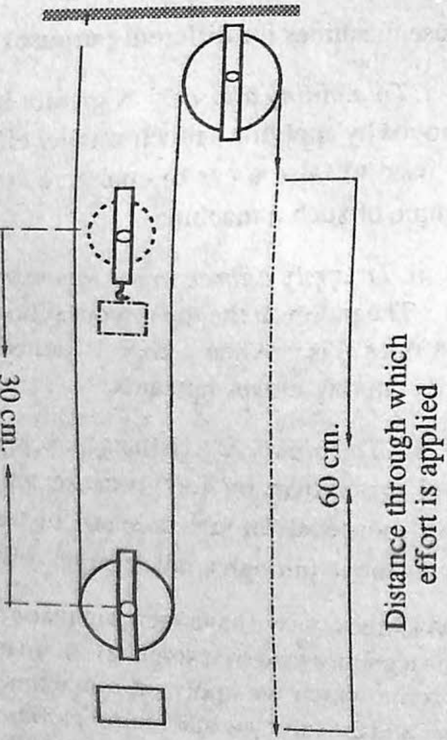

30 cm.
Distance through which load is raised
60 cm.
Distance through which effort is applied

Fig. 2.21 System of pulleys

The ratio of the distance through which the effort is applied to the distance through which the load is overcome is called the velocity ratio (*V R*) Velocity ratio for a machine depends upon its design. In the system of pulleys in Fig.2.21.

the velocity ratio (VR) $= \frac{60}{30} = 2$

Since it is a ratio VR has no units.

EFFICIENCY

The efficiency of a machine is defined as the ratio of the output work done by the machine to the input work done on the machine.

Efficiency =

$$\frac{\text{work done by machine in moving load}}{\text{work done on machine by applying effort}}$$

Now, work done in moving load

= load x distance moved by load and,

work done on machine by applying effort

= effort x distance moved by effort.

therefore, efficiency

$$= \frac{\text{load}}{\text{effort}} \times \frac{\text{distance moved by load}}{\text{distance moved by effort.}}$$

Now, load/effort = MA, and

$$\frac{\text{distance moved by load}}{\text{distance moved by effort}} \quad \frac{1}{VR}$$

Hence, efficiency

$$= MA \times \frac{1}{VR} = \frac{MA}{VR}$$

Suppose the mechanical advantage (MA) of a machine is 1.6 and its velocity ratio (VR) is 2 then its efficiency will be

$$\frac{MA}{VR} = \frac{1.62}{2} = 0.8$$

In practice, VR is always greater than the MA. So the efficiency is always less than 1.

Efficiency is expressed as a percentage. Therefore, the value for efficiency that we got above, must be converted to a percentage by multiplying it by 100.

$$0.8 \times 100 = 80\%$$

BLOCK AND TACKLE

In Class 6 you learnt about simple machine using single pulleys. When you combine two or more pulleys to work together, then you call the combination a *pulley system.* In a pulley system, the velocity ratio can be increased by increasing the number of pulleys. As the velocity ratio increases the mechanical advantage also increases.

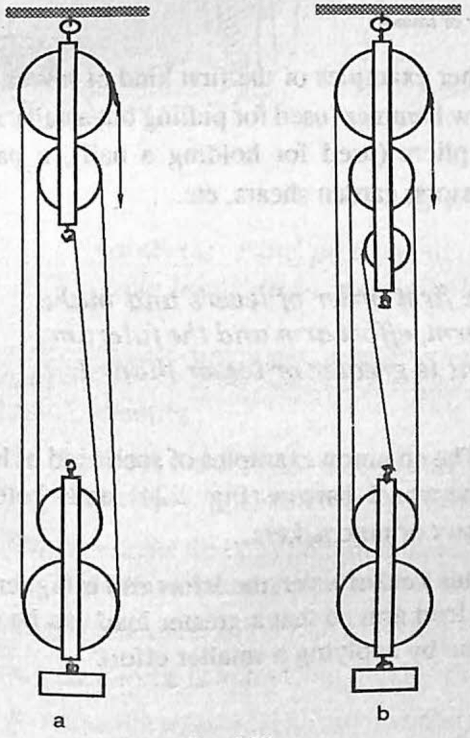


Fig. 2.22

The pulley system (called a block and tackle) usually has two blocks of pulleys (see Fig.2.22). One block is fixed to a immovable point. The other block is moveable. Each block may have equal number of pulleys or the upper block may have one more. A single rope (the tackle) over the block and effort is applied at the free end.

In practice, the pulley wheels in each block are mounted side by side on a common axle and are of the same size. If an odd number of pulleys is used the fixed end of the rope is tied to the lower end. If an even number of pulleys is used the fixed end of the tackle is tied to the upper block.

Suppose, as in Fig. 2.22 a the number of pulleys is 4. In such a block and tackle arrangement, for a load to be raised through a distance y, the four sections of the rope connecting the two blocks will have to be shortened by a distance of y each. In other words, the effort will have to move through a distance of 4y. The mechanical advantage, as you can see, is 4.

Consider a block and tackle of 7 pulleys used to lift a overturned car which exerts a load of 500 kgf. The effort applied is 100 kgf. Find the efficiency of the block and tackle.

$$MA = \frac{\text{load}}{\text{effort}} = \frac{500\text{ kgf}}{100\text{ kgf}} = 5$$

$$VR = \text{number of pulleys} = 7$$

$$\text{efficiency} = \frac{MA}{VR} = \frac{5}{7} = 0.714 = 71\%$$

TYPES OF LEVERS

Depending on the relative positions of the fulcrum in relation to the effort applied and the load overcome, there are three kinds of levers:

i. *First order lever* : In a lever of the first order, the fulcrum is in between the load and the effort. This, as you would have realised, is the case of the beam balance or physical balance. In a balance, the effort and load arms are equal and mechanical advantage is 1, if the efficiency is 100%.

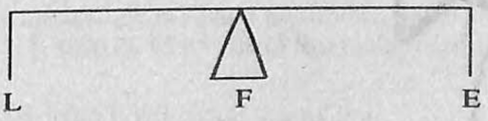


Fig. 2.23 (a)

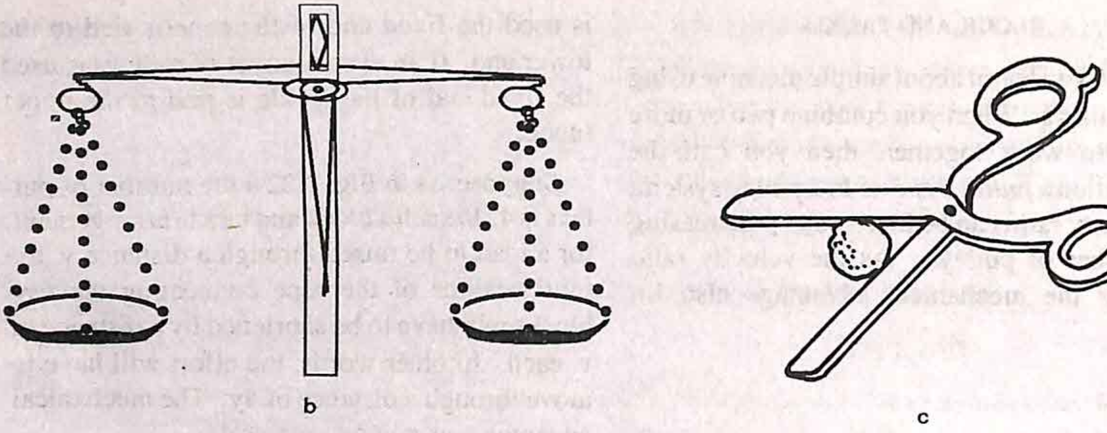


Fig 2.23 First order of levers

A crow-bar is also a first order lever.

In a crow-bar the effort arm is longer than the load arm, so the MA is more than 1 and a greater load may be lifted by applying a smaller effort.

Other examples of the first kind of levers are a claw hammer (used for pulling out a nail), a pair of pliers (used for holding a nail), a pair of scissors, garden shears, etc.

> **Activity 14 :** *Observe instruments of the first order of levers and make drawings of them indicating the load arm, effort arm and the fulcrum. Find out if the M.A. of each instrument is greater or lesser than 1.*

ii. *Second order lever* **:** In a lever that belongs to the second order, the fulcrum is at one end of the lever and the effort is applied near at the other end. The load is in between the fulcrum and the effort.

The common examples of such kind of levers is the wheel barrow (Fig. 2.24), and betel nut cutters or nutcrackers.

In this kind of lever, the effort arm is bigger than the load arm so that a greater load can be overcome by applying a smaller effort.

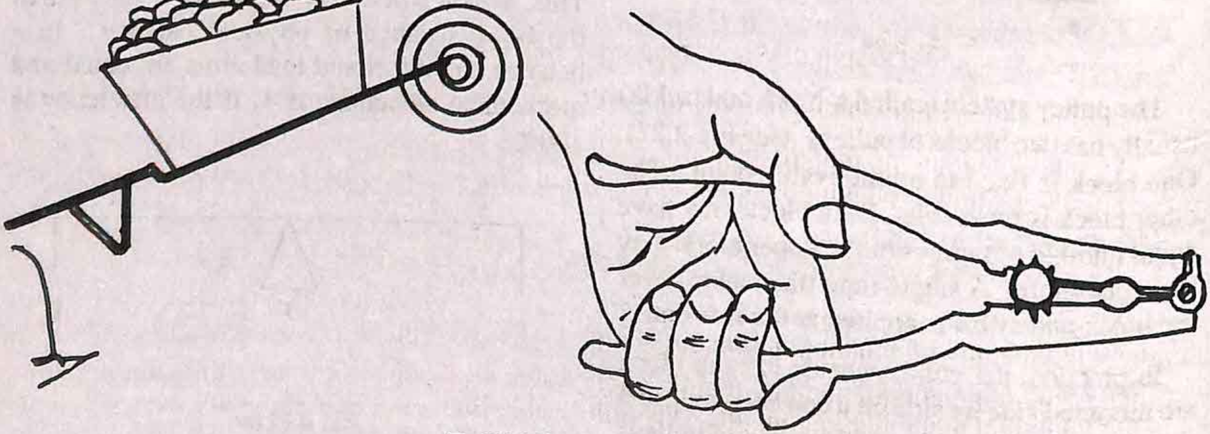


Fig 2.24 Second order of levers

Activity 15 : *Name two more examples of second order lever.*

Lever of the third order : In levers of the third order, the effort is applied between the load and the fulcrum. The forceps you use to remove the milligram weights from the box of weights for the physical balance, tongs like the ones used to lift ice cubes from an ice bucket, a shovel, etc.

The load arm, as you notice, is longer than the effort arm, so you need a greater effort to overcome a small load.

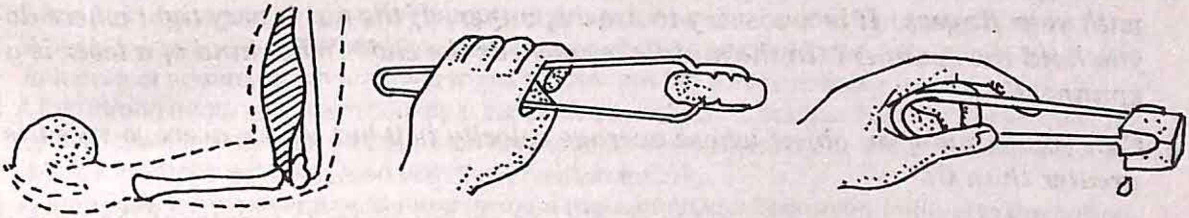


Fig. 2.25 Third order of levers

Activity 16 : *Find pictures of appliances of all three orders of lever and paste them up in your notebook.*

Basic concepts

1. Speed is the distance a body moves in one unit of time and velocity of a body is its rate of change of displacement per unit of time.
2. A quantity that has both magnitude and direction is a vector quantity and quantity that has magnitude only is a scalar quantity.
3. Acceleration is the rate of change of velocity with respect to time.
4. By a force is something that tends to change the velocity of a body.
5. A single force which can have the same effect on a body as two or more forces actually acting on the body, is the resultant of those forces.
6. Inertia is the tendency of an object to stay at rest or resist change in its motion.
7. The centre of gravity of a body is a point where the weight of the body appears to act. The stability of a body depends on the position of its centre of gravity and its base area.
8. A machine is any device that transfers a force applied at one point to another point where it is used. The turning effect of a force is known as its torque or the moment of force.
9. A lever is a simple machine capable of turning a fixed point called the fulcrum.
10. The mechanical advantage of a machine is the ratio of the load overcome to the effort applied (M.A. = L/E). The efficiency of a machine is the ratio of the output work done by it to the input work do on it.

Some investigatory projects/activities

1. *Most of the joints in your body use the principle of levers for mechanical advantage, that is, to use a smaller effort to move a bigger load. Can you identify the major joints in your body which use the principle of the lever? With the help of your teacher make drawings of these lever-like joints. Mark where the effort, load and fulcrum are in each case.*

   Discuss and decide to which order of levers each joint belongs.

2. *It is difficult, or almost impossible, to remove the nut on the hub of your bicycle wheel with your fingers. It is necessary to use a spanner. If the nut is very tight where do you hold the spanner? In the middle or towards the end? What kind of a lever is a spanner?*

3. *Can you think of an object whose average velocity is 0 but whose average speed is greater than 0?*

4. *The tip of the minute hand of a big clock is 14 cm long from the centre of the clock's face. Find the speed of a point on the tip of the minute hand.*

REVISION TIME

I. Choose the correct answer :

1. A quantity that has magnitude only is ....
   a. a force. b. a vector. c. a scalar quantity.
2. When the velocity of a body is increasing, it is ....
   a. deceleration. b. turning. c. accelerating. d. proving Newton's first law.
3. Newton's first law of motion employs the principle of ....
   a. catalysis. b. action of levers. c. inertia. d. simple machines.
4. The stability of a body depends on its ....
   a. mass. b. base area. c. velocity. d. torque.
5. A machine transmits forces and can multiply ....
   a. the applied force. b. the work input. c. the inertia of a body.

II. Differentiate between the following pairs :

1. acceleration and retardation.
2. speed and velocity.
3. vector and scalar.
4. force and work.
5. mechanical advantage and velocity ratio.

III. Fill in the blanks :

1. Negative acceleration is also known as ________

2. The law of inertia is the same as ________ ________ of ________ .
3. The stability of a body depends on it ________ and ________ .
4. The ________ of a body depends on its mass.
5. The force that must be applied opposite to the resultant in order to keep a body in equilibrium is called ________ .
6. The single force which is the equivalent of two or more forces is called ________ .

IV. Draw diagrams only to illustrate the three types of levers.

V. Write short notes on :

1. Draw a distance-time graph of an aeroplane flying due south at a constant speed of 400 km/hr.
2. What is the principle of the parallelogram of forces? If the parallelogram of forces of two forces is a perfect square, at what angles to each other are the forces acting.
3. A thin strong beam of uniform density is supported exactly at its centre. Two forces of 5 newtons and 10 newtons act on it. If the beam balances (is in equilibrium), at what distance must the 10 newton force act compared with the 5 newton force?
4. A man pulls a rope over a pulley and raises a mass of 50 kg. The pulley is fixed to the ceiling. When the man is pulling on the ropes and raising the mass, what is the downward force applied on the ceiling.
5. Distinguish between displacement and distance. How is speed different from velocity?
6. Define scalar and vector quantities. Give three examples of each.
7. Define force and its unit (SI).
8. When does a force do work? What is the unit of work?
9. What is meant by torque? Give its units.
10. What is a machine? What are the things a machine can do?

VI. Write detailed answers on the following :

1. State Newton's first law of motion. Give two examples to explain it.
2. What is meant by the centre of gravity of a force? Explain stable, unstable and neutral equilibrium giving two examples for each.
3. What is the mechanical advantage, velocity ratio and the efficiency of a machine? Why is the efficiency of a machine always less than 1 or 100% ?
4. State and explain the principle of the parallelogram of forces.
   Two forces, $F_1 = 7$ kgf and $F_2 = 4$ kgf make an angle of 60° with each other when acting on a point A. Find by drawing, using any convenient scale, the magnitude and direction of the resultant.

VII. Give scientific reasons :

1. Why are standing passengers not allowed on the upper deck of a double decker omnibus ?

3. Hydrostatics

Density and relative density - thrust and pressure - fluid pressure and transmission of pressure in fluids - buoyancy and Archimedes principle - atmospheric pressure and its measurement - working of pumps.

In Chapter 2 you learnt about the action of forces and the transmission of forces in solid bodies. You also studied the working of simple machines which use the principles of mechanics to transmit and multiply forces.

Forces act on all bodies which are in motion or at rest (in equilibrium). Forces act on liquids and gases, too but, because the behaviour of liquids and gases is different from that of solids, forces act in a different manner on liquids and gases. In other words, the behaviour of liquids and gases (liquids and gases together are called *fluids*) is different from the behaviour of solids.

In this chapter you will learn about the action and transmission of forces in fluids (that is, liquids and gases). But before that, you must learn something more about a few things you are already familiar with.

3.1 Density and relative density

You are aware that equal volumes of different substances have very different masses. For instance you already know that the density of a substance is defined as the mass per unit volume of a substance.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$
$$= \text{gm/cc or kg/m}^3$$

You will notice when you study how and why bodies float and why it is useful to know how many times a substance is heavier or lighter than water. This information is useful for various other purposes too. When we say that a substance is so many times heavier or lighter than water, we are comparing the density of this substance with the density of water.

The ratio of the density of a substance to the density of water is known as its *relative density,* formerly known as its *specific gravity.*

$$\text{relative density} = \frac{\text{mass of any volume of the substance}}{\text{mass of an equal volume of water}}.$$

The density of a substance relative to the density of water may also be defined as *the ratio of the weight of a certain volume of a substance to the weight of an equal volume of water.*

$$\text{relative density (r.d.)} = \frac{\text{weight of any volume of a substance}}{\text{weight of an equal volume of water}}$$

If we consider unit volume of a susbtance the mass of unit volume of a substance is its density. The ratio of the weight of unit volume of a substance to the weight of unit volume of water is the same as the ratio of the density of a substance to the density of water.

Therefore, relative density =

$$\frac{\text{density of a substance}}{\text{density of water}}$$

Suppose the density of mercury is 13.546 gm/cc. You know that the density of water is 1 gm/cc. Now, relative density of mercury is equal to the ratio of the density of mercury to the density of water.

relative density of mercury =

$$\frac{\text{density of mercury}}{\text{density of water}}$$

$$= \frac{13.546 \text{ gm/cc}}{1 \text{ gm/cc}}$$

$$= 13.546.$$

When you divide the value of one density by the value of another density, the units cancel each other. Therefore, relative density (which is only a ratio) has no units. Since the density of water is 1 gm/cc in the CGS system of units, the r.d. of a substance is numerically its density in the CGS system.

It is important to note that relative density is only a ratio — a number. It has no units.

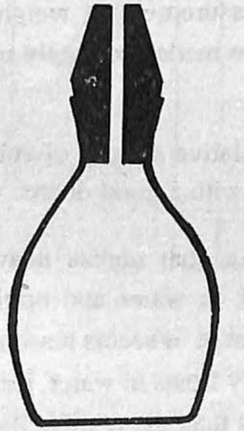


Fig. 3.1 The relative density bottle

RELATIVE DENSITY BOTTLE

In the laboratory we use a special bottle to find the relative density of different substances. This bottle is called a relative density bottle (Fig. 3.1).

This is a flat bottomed glass bottle, with a volume of about 50 cc. A water-tight glass stopper fits into the neck of the bottle. The stopper has a narrow bore running from one end to the other. When using the bottle, it is carefully filled with water or any other liquid and the stopper is inserted tightly. Some of the liquid will ooze out through the bore in the stopper. The liquid that overflows should be wiped off with a clean piece of cloth or blotting paper. As you can see this bottle will always contain exactly the same volume of any given liquid, temperature remaining constant.

The relative density bottle is most useful for finding the relative density of liquids and of solids in the form of powder or small bits like sand or glass beads.

FINDING THE RELATIVE DENSITY OF A LIQUID USING THE DENSITY BOTTLE

Take a clean, dry relative density bottle. Find its weight when it is empty (W_1). Then fill it with the liquid whose relative density you want to find and find the weight of the bottle filled with the liquid (W_2). Pour out the liquid and rinse the bottle well with water. Now, fill the bottle with water and find the weight (W_3).

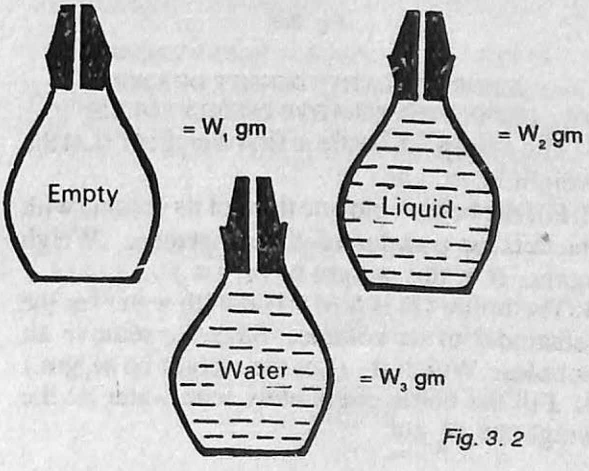


Fig. 3. 2

The readings taken are:

1. Weight of the empty r.d. bottle = W_1 gm.
2. Weight of the r.d. bottle filled with liquid = W_2 gm.
3. Weight of the r.d. bottle filled with water = W_3 gm.

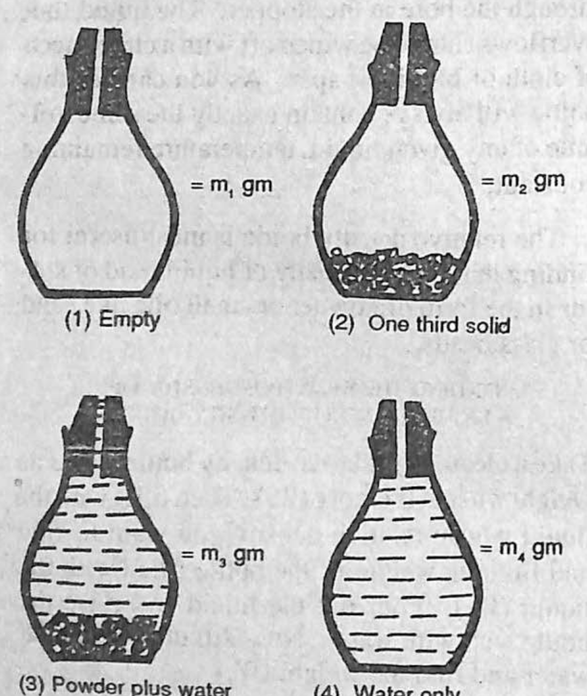
Therefore, weight of liquid = $W_2 - W_1$ gm
and weight of water = $W_3 - W_1$ gm

Now, relative density =

$$\frac{\text{weight of any volume of liquid}}{\text{weight of an } \textit{equal} \text{ volume of water}}$$

$$= \frac{W_2 - W_1}{W_3 - W_1}.$$

Activity 1: *Why is it useful to weigh the liquid first and water afterwards? Discuss this with your teacher.*



(1) Empty (2) One third solid

(3) Powder plus water (4) Water only

Fig. 3.3

FINDING RELATIVE DENSITY OF A SOLID USING THE RELATIVE DENSITY BOTTLE

1. The empty r.d. bottle is first weighed. (Let the weight be m_1 gm.)
2. Fill the bottle upto one third of its volume with the bits or powder of the substance. Weigh again. (Let this weight be m_2 gm.)
3. The bottle (2) is now filled with water for the remainder of its volume. Shake to remove air bubbles. Weigh it. (Let the weight be m_3 gm.)
4. Fill the bottle completely with water let the weight be m_4 gm.

Wt. of empty r.d. bottle	= m_1 gm.
Wt. of bottle + solid	= m_2 gm.
Wt. of bottle + solid + water	= m_3 gm.
Wt. of bottle + water	= m_4 gm.

The relative density is calculated as follows :

r.d. of the solid =

$$\frac{\text{mass of any volume of solid}}{\text{mass of an equal volume of water}}$$

$$= \frac{\text{mass of solid bits (2)}}{\text{mass of water in (4)} - \text{mass of water in (3)}}.$$

$$= \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)}$$

Advantages of using the density bottle

a. No volume measurements are involved.

b. Only measurement of weights is involved. These can be made accurately using a physical balance.

Thus, the relative density of substances can be determined with a good degree of accuracy.

You know that bodies heavier than water usually sink in water and bodies lighter than water float in it. It seems reasonable to suppose that if a body floats in water, its relative density must be less than the relative density of water.

Activity 2: *a. Calculate the relative density of water.*
b. Write down your own weight in kilograms. What is your weight in grams? The density of the human body is about the same as that of water. Use this fact to calculate the volume of your body.

Activity 3: *Take a cube of ice and place it in a vessel of water. Does it float or sink? How much of the ice cube is above water and how much below? What can you conclude about the relative density of ice?*

Activity 4: *Take a glass jar. Pour some water into it and then pour an equal quantity of kerosene oil. What do you observe? Try the same experiment first pouring the kerosene oil into the glass jar and then the water. What can you conclude about the relative density of kerosene?*

3.2 Thrust and pressure

In the previous chapter you learnt about forces and you know that the direction and point of application of the force has a significance. Now we will see that the area over which you apply a force also matters. For example, if you accidentally sit on a drawing pin, you will be applying a force on it. Now, if the flat side is uppermost, you won't mind it very much, but, it will be very different if the pointed side is uppermost. This is because of the area over which you have applied the force.

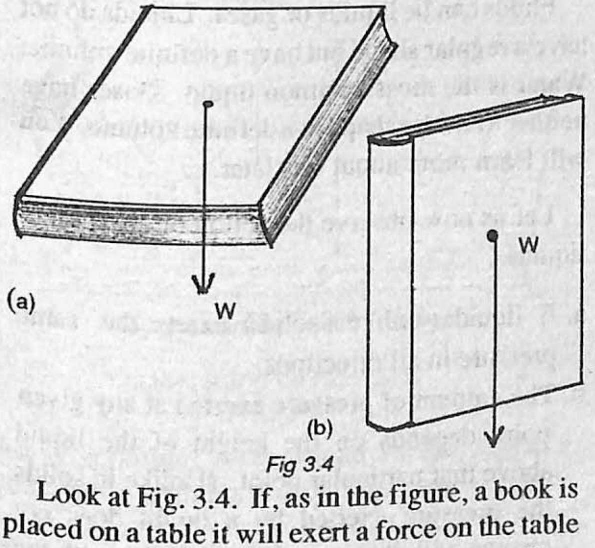


Fig 3.4

Look at Fig. 3.4. If, as in the figure, a book is placed on a table it will exert a force on the table equal to its weight. This force acting perpendicular to the surface of the table is called *thrust*. The thrust which the book exerts on the table will be the same whether the book is placed horizontally or vertically. But, when the book is placed horizontally the thrust is distributed over a greater area than when it is placed vertically.

In the above example, when the book is placed vertically, the thrust is spread over a smaller area. So, each point of the table under the book will have a greater force acting on it, than when the book is placed horizontally.

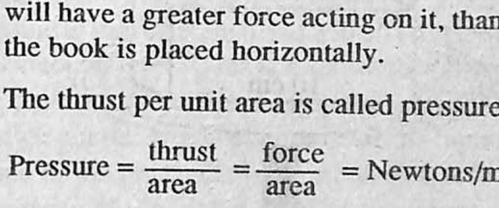
The thrust per unit area is called pressure.

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} = \frac{\text{force}}{\text{area}} = \text{Newtons/metre}^2.$$

The unit of pressure is the *pascal*. A force of 1 newton acting on an area of 1 square metre is one pascal.

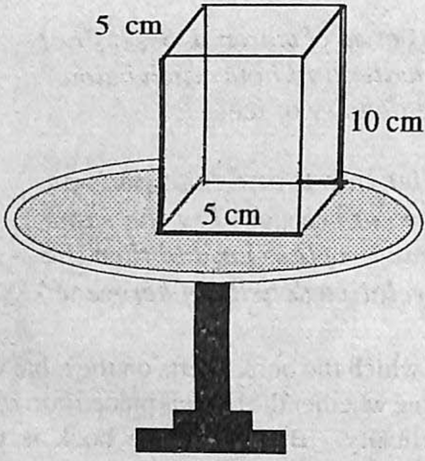
1 newton / metre^2 = 1 pascal.

Problem : A brick whose dimensions are 5 cm x 5 cm x 10 cm, weighs 2.5 kg.

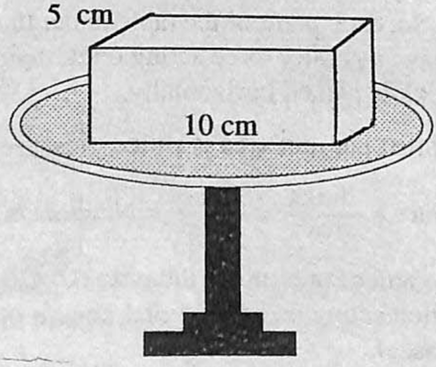


a) If the brick is kept on a table, what is the thrust it exerts on the table?

b) What is the pressure exerted on the table by the brick, if it is placed upright?



c) What is the pressure exerted on the table if the brick is laid on its side?



Solution : a) The thrust exerted by the brick is equal to its weight. Therefore the answer is 2.5 kg.

b) Pressure = $\frac{\text{thrust}}{\text{area}}$

The area of the brick in contact with the table, when it is kept upright (see figure) is $5 \times 5 = 25 \text{ cm}^2$.

$$\therefore \text{pressure} = \frac{2.5 \text{ kg}}{25 \text{ cm}^2} = 0.1 \text{ kg/cm}^2.$$

(Convert the answer into Pascal units. 1 Pascal = 1 kg/m^2.)

c) The area of the brick in contact with the table, when it is laid on its side $= 5 \times 10 = 50 \text{ cm}^2$.

$$\therefore \text{pressure} = \frac{2.5 \text{ kg}}{50 \text{ cm}^2} = 0.05 \text{ kg/cm}^2.$$

(Convert the answer into Pascals, i.e. kg/m^2.)

3.3 Fluid pressure

So far we have studied force and pressure in connection with solids. Solids have a definite shape and the pressure of a solid acts downwards at its base. Hence the pressure exerted by a solid changes with the area of its base.

There are also bodies which do not have a definite shape. Even if a small force is exerted on them, they change shape. Such bodies, will move downward and flatten out as much as possible because of the earth's force of gravity. In behaving like that they will take the shape of any container in which they are kept. If the container is tipped or a hole is made in its bottom, the material will pour out. It is this ability to pour or flow that gives such bodies the name, fluids.

Fluids can be liquids or gases. Liquids do not have a regular shape but have a definite volume. Water is the most common liquid. Gases have neither a regular shape or a definite volume. You will learn more about this later.

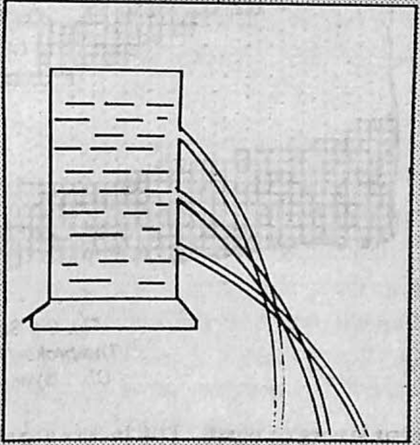
Let us now observe the action of pressure in liquids.

a. A liquid (unlike a solid) exerts the same pressure in all directions.
b. The amount of pressure exerted at any given point depends on the height of the liquid above that particular point. (Unlike in solids the pressure exerted by a liquid does not change with the area of the base but with the height of the liquid.)

Activity 5 : *Take a tin can and make holes in it with a nail. Put the holes at different places round the can but at the same height. Fill the can with water . (You can put the can under a tap so that water flows in at the same rate as it flows out.).Observe how the water spouts out.*

Now take another can and make the same number of holes as in the other can. But make the holes at different heights, one near the top, one near the middle and so on. Watch how the water flows out of the holes this time.

Can you explain the difference in the way in which water flows out of the holes in both the cans from what you have learned so far?



The two facts about the action of pressure in liquids given above was used by the French mathematician Blaise Pascal (1623-1662) to state his famous principle. *Pascal's principle or law states that the pressure exerted at any point on a confined liquid is transmitted unchanged to every other point in the liquid.*

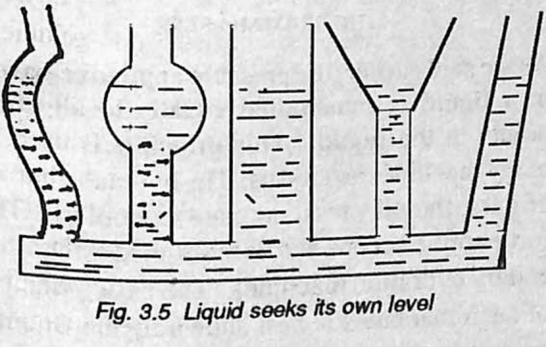


Fig. 3.5 Liquid seeks its own level

TRANSMISSION OF PRESSURE IN LIQUIDS

Many machines used around us use Pascal's principle to multiply forces. The same property is also responsible for the artesian well and water from a distant tank flowing out through the taps in our homes.

The free surface of a liquid in a vessel is horizontal. If a liquid is poured into a vessel which has many sections connected together (Fig. 3.5), the liquid in the different tubes will all be at the same horizontal level. This is because the pressure at a point in a liquid is transmitted equally to all other points. If you pour more of the liquid into one of the tubes, the pressure in that tube rises because of the higher level of the liquid. This pressure is transmitted to all the other points in the liquid and the liquid moves till the pressure in all parts of the liquid is equal. Hence, the liquid stands at the same level in each tube. This property of a liquid is what makes water flow all the way from a tank at a height and come out at the open taps in the house. We usually express this property of liquids by saying that *a liquid seeks its own level.*

These examples given below demonstrate the principle of liquids finding their own level :

Artesian wells : In some places the earth's surface is like a saucer (a valley between two hills, for example). Under this curved surface there

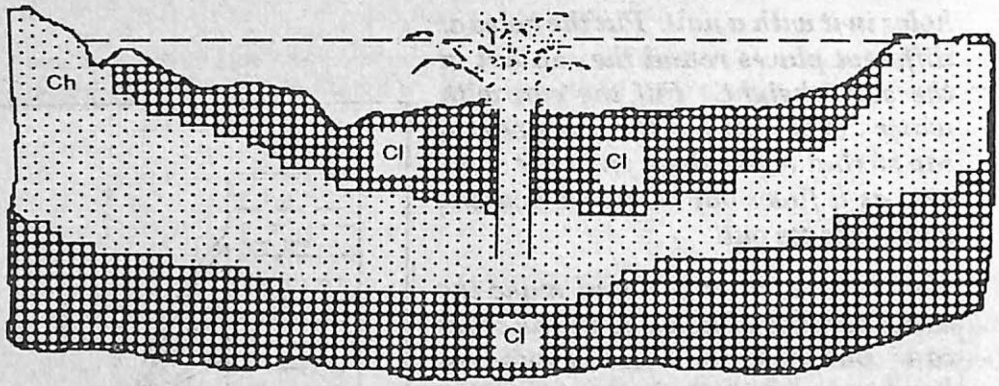


Fig. 3.6 Section of an artesian well
The broken line shows the water level.
Ch. , layer of chalk; Cl., layer of clay

are different layers of earth. The layers are alternately porous like sand, and non-porous like clay. In such places, if a well is bored through the non-porous layers into the porous layer, water will gush out as a spring. Such springs are called Artesian wells (Fig. 3.6). This method of obtaining a supply of water was first used in Artois, a province in France, hence the name Artesian wells.

The water level : The water level consists of a pair of glass tubes connected by a metal tube and nearly filled with water (Fig. 3.7).

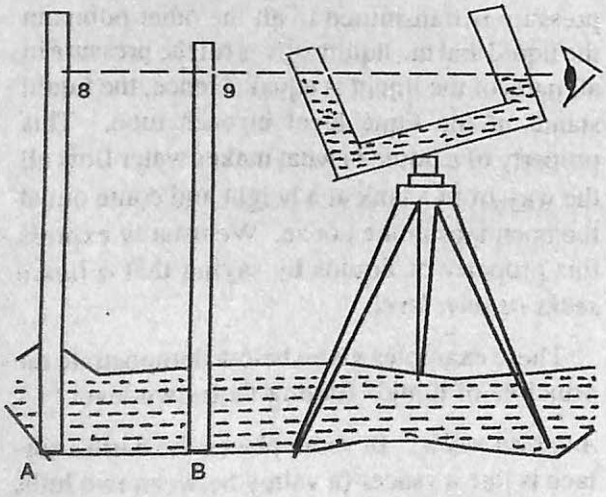


Fig. 3.7 The water level

An observer looks along the common level of the water surfaces in the tubes. Another person moves a plate up and down a graduated bar till it is seen in line with the water surface in the tubes. The position of the plate on the bar is read. The bar is then taken to another part of the ground and the reading of the plate on the scale is again taken. If the two readings are the same then the two places are at the same level. If the readings differ, then the difference gives the height of one place over the other.

THE BRAMAH PRESS

As we said earlier, the pressure applied at a point in a liquid is transmitted equally to all other points in the liquid. This principle is used in many machines around us. The hydraulic brakes of cars, the oil press, etc., are examples. The force applied at one end, is multiplied at the other end by hydraulic machines. The basic principle of such machines is best shown by the Bramah press (Fig. 3.8).

In the figure you see two cylindrical vessels connected together. Each cylinder has a tight fitting piston. Let the areas of the cylinders be in the ratio 10 : 1. Let the piston in the small cylinder be forced down with a weight of 1 kg. Now the pressure applied through the liquid is

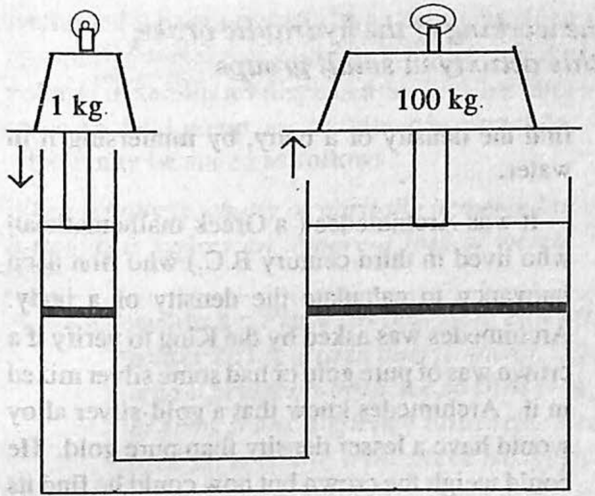


Fig. 3.8 The principle of the Bramah press

$1 kg/m^2$. Since the area of the piston in the large cylinder is $10 m^2$ the total thrust on it will be $1 kg \times 10 m^2 = 10 kg/m^2$. We see that by applying a 1 kg force on the smaller piston, the larger piston can be made to raise a weight of 10 kg.

But have we got more work from the big piston than the work done by the small piston? What really happens is when the small piston moves down by 1 metre, it displaces $1 m^2 \times 1 m = 1 m^3$ of liquid. To accommodate the same volume of liquid, the large piston has to only move $1 m^3/10 m^2 = 0.1 m$.

We know, work done is force multiplied by distance through which the body moves in the direction of the force. The work done by both the pistons is the same. Though a small force applied on the small piston is multiplied into a bigger force at the larger piston, the small piston has to move through a correspondingly longer distance than the larger piston. (This is similar to what we learned about levers.)

The principle of the Bramah press is used in the making of hydraulic presses and lifts (like the one that raises a car in a service station).

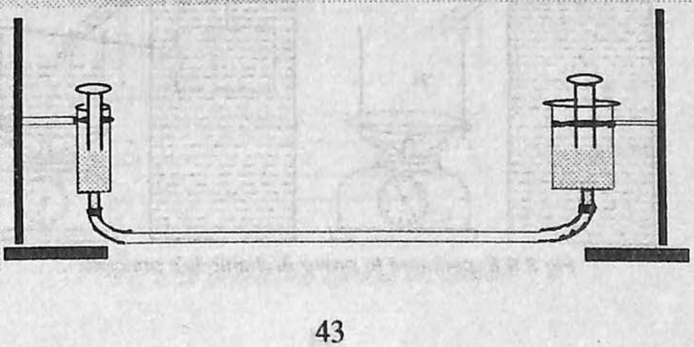
Activity 6: *You can make a model Bramah press.*

Obtain two plastic disposable medical syringes of different sizes (say, one of 5 ml capacity and another of 15 ml capacity). Remove the plungers and fix them on two stands using light but firm clamps so that their upper ends are at the same height. Their nozzles should be pointing downwards.

Connect the nozzles of the two syringes using a piece of rubber tubing. The connections should be air tight. Pour water into the two syringes till both are about 3/4 ths full. Fit the plungers in both the syringes.

Push the plunger of the big syringe and feel the force on the plunger of the small syringe. Then push the plunger of the small syringe while holding the plunger of the large syringe. Feel the force again.

Do the results bear out Pascal's law and the principle of the Bramah press?



Activity 7: *Find out details about the working of the hydraulic brake, hydraulic lift and oil press. Do this activity in small groups.*

3.4 Archimedes principle

BUOYANCY

Try lifting a somewhat big rock out of a pond. As the rock comes out of the water it will seem to suddenly become heavier. The rock seems to have lost weight when it was immersed in water. Now, float a block of light wood on water. Try pushing the wooden block under the water. You will feel the water pushing the block up as you try to push it down. In both cases the reason is that water is exerting an upward force.

The upward force which a liquid exerts on an object placed in it is called the buoyant force. Ships float on water and you are able to float in a swimming pool because of this buoyant force.

ARCHIMEDES PRINCIPLE

When an object is immersed in a liquid, it will displace a volume of liquid equal to its own volume. It will also weigh less. Its loss of weight will be equal to the upward buoyant force exerted by the liquid. These facts can be used to find the density of a body, by immersing it in water.

It was Archimedes (a Greek mathematician who lived in third century B.C.) who first used buoyancy to calculate the density of a body. Archimedes was asked by the King to verify if a crown was of pure gold or had some silver mixed in it. Archimedes knew that a gold-silver alloy would have a lesser density than pure gold. He could weigh the crown but how could he find its density ?

The idea came to him, or so the story goes, when he was lowering himself into his bathtub and saw water overflowing from it. He realised that when a body is immersed in water/liquid it displaces water or liquid equal to its volume. He was so excited by the answer to his problem that he is said to have run naked through the streets of Syracuse crying "Eureka ! Eureka ! (I've got it! I've got it !). Hence, the vessel used to measure volume by displacement is called an Eureka can.

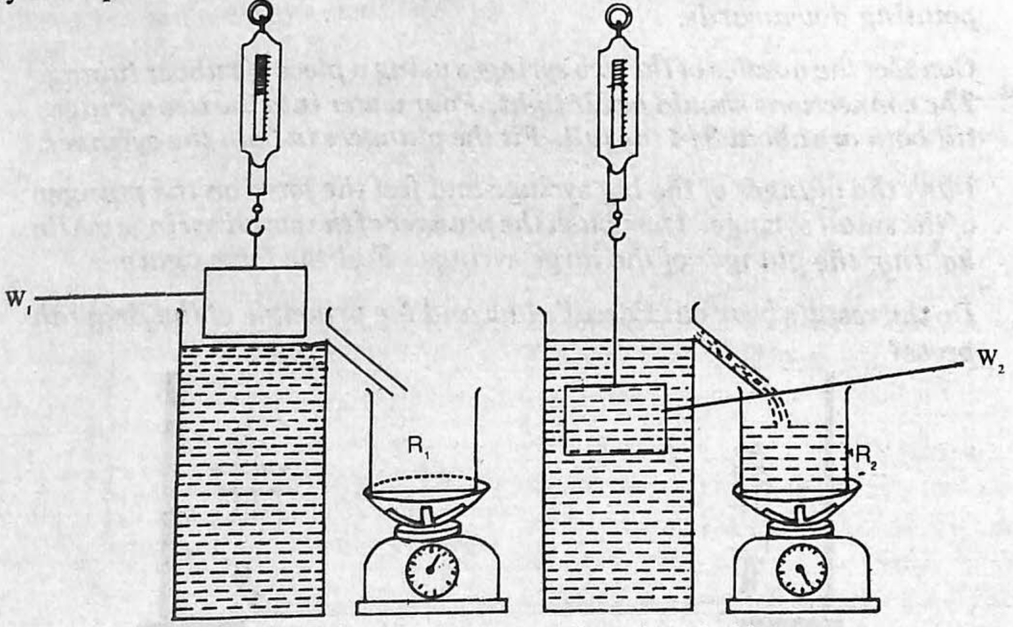


Fig 3.9 Experiment to prove Archemede's principle

Archimedes had discovered the relation between the loss of weight of body in a liquid and the volume of the liquid displaced by it. This later came to be known as Archimedes principle, which may be stated as follows :

When a body is wholly or partially immersed in a liquid, it suffers an apparent loss of weight equal to the weight of the liquid displaced by the body.

Hence by putting the crown into water he could measure the amount of water displaced by it and from this calculate its density.

These results are explained by Archimedes principle.

Activity 8 : *Place an overflow can on a wooden block. Fill the can with water till it starts overflowing. Place an empty beaker on the tray of a compression balance so that it is just below the spout. Hang a piece of iron from a spring balance. Record the weight of the beaker (R_1) and that of the iron piece hung from the spring balance (W_1).*

Now, gradually lower the iron into the water in the can till it is completely immersed. Record the apparent weight of the iron piece in the water, (W_2). Also record the weight of the beaker with the displaced water (R_2). It will be seen that the weight of the water displaced ($R_2 - R_1$) is equal to the loss of weight of the iron piece when immersed in water, ($W_1 - W_2$).

VERIFICATION OF ARCHIMEDES PRINCIPLE

Socket and cylinder experiment **:** The socket and cylinder consists of a metal cylinder B which fits exactly into the socket A. The cylinder is first suspended from a hook at one end of a balance with the cylinder below the socket (Fig. 3.10). The socket and cylinder are balanced by placing necessary weights on the other pan of the balance.

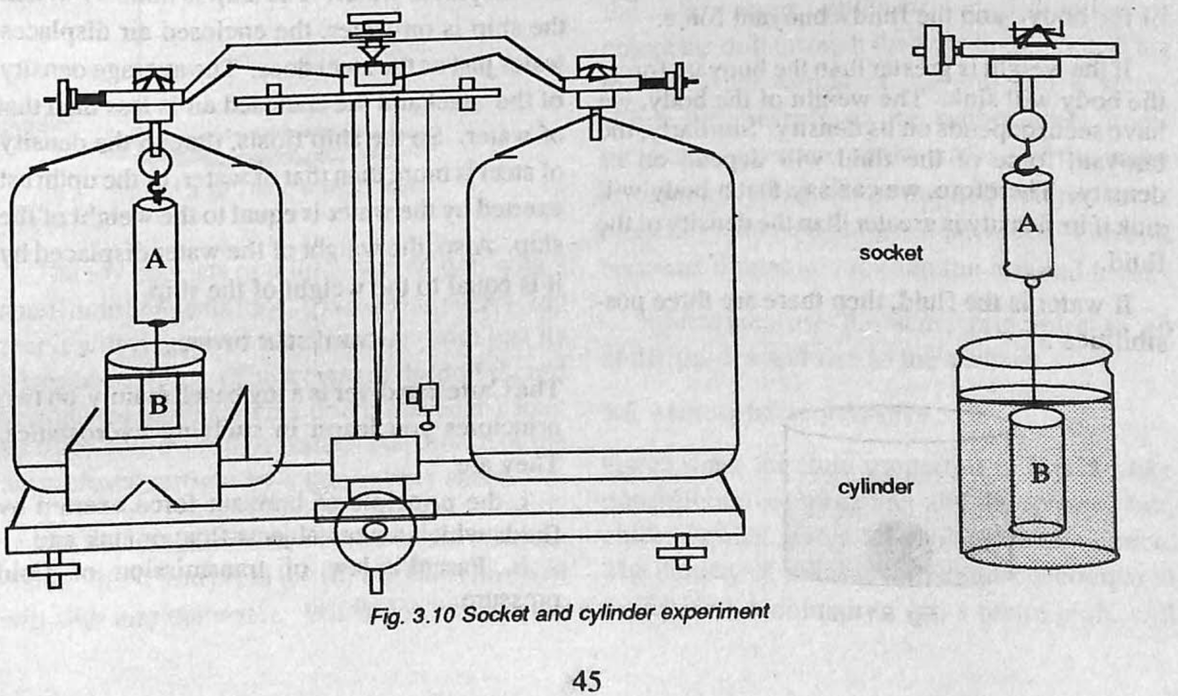


Fig. 3.10 Socket and cylinder experiment

A beaker of water is kept on a stand so that the cylinder is immersed fully in the water. The cylinder will now appear to have become lighter and the balance will lose its equilibrium.

Water is next poured into the socket. It will be found that the equilibrium of the balance is restored when the socket is full. Since the internal volume of the socket is the same as the volume of the cylinder, the loss of weight of the body is equal to the weight of water displaced by the body.

FLOATING AND SINKING

When an object is partly or fully immersed in a fluid, two forces act on it :

a. The downward pull of the earth which is equal to its weight. The weight of the body = its volume x its density .

b. The buoyant force which the fluid exerts on it in the opposite direction. The buoyant force is equal to the weight of the fluid displaced.
Weight of fluid displaced = volume of fluid displaced x density of fluid.

Whether a body sinks or floats in a fluid depends on the relationship between the weight of the body, and the fluid's buoyant force.

If the weight is greater than the buoyant force, the body will sink. The weight of the body, we have seen, depends on its density. Similarly, the buoyant force of the fluid will depend on its density. Therefore, we can say that a body will sink if its density is greater than the density of the fluid.

If water is the fluid, then there are three possibilities :

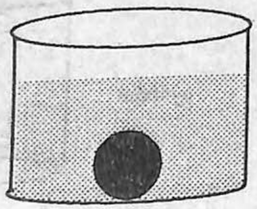


Fig. 3.11 (a)

i. If the relative density of the body is greater than that of water, i.e., greater than 1, then the body will sink to the bottom of the water (Fig. 3.11a).

ii. If the relative density of the body is 1, or very close to that of water, then it will float, completely immersed in the water (like a submarine or a fish) (Fig. 3.11b).

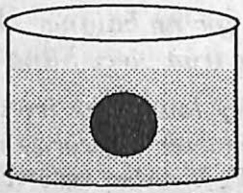


Fig. 3.11 (b)

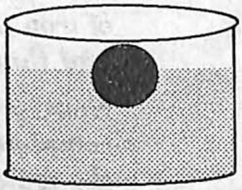


Fig. 3.11 (c)

iii. If the relative density of the body is less than that of water, it will float above water like a ship (Fig. 3.11c). (That fact that a steel ship floats, it does not mean that the density of steel is less than that of water. It is not the steel of the ship alone that displaces water. The ship is hollow. When the ship is on water, the enclosed air displaces water just as the steel does. The average density of the steel and the enclosed air is less than that of water. So the ship floats, though the density of steel is more than that of water, or the upthrust exerted by the water is equal to the weight of the ship. Also, the weight of the water displaced by it is equal to the weight of the ship.

CARTESIAN DIVER

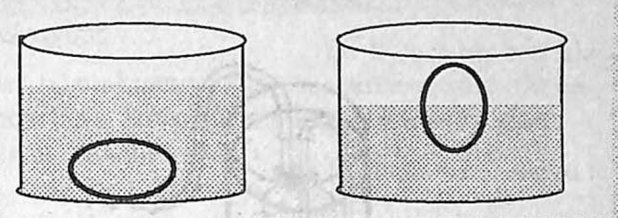
The Cartesian diver is a toy based mainly on two principles you learnt in studying hydrostatics. They are

i. the principle of buoyant force exerted by fluids which makes objects float or sink and

ii. Pascal's law of transmission of fluid pressure.

Activity 9 : *Shape a piece of tin or aluminium foil into the form of a little boat and float it on water in a pan. Now squeeze the metal foil into a small ball and try to float it on the water. What do you observe? What explanation can you give for what happened?*

Activity 10 : *Place an egg in a glass of fresh water and observe it. Now add salt to the water and see if the egg floats. Can you explain what happens? How does this experiment explain the fact that ships float higher in ocean water than they do in fresh water?*



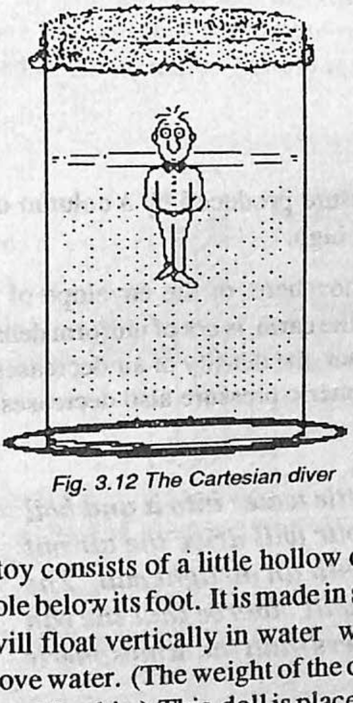


Fig. 3.12 The Cartesian diver

The toy consists of a little hollow doll with a small hole below its foot. It is made in such a way that it will float vertically in water with just its head above water. (The weight of the doll should be adjusted for this.) This doll is placed in a long jar three-fourths full of water. The mouth of the jar is closed airtight by a thin rubber sheet.

The doll usually floats with its head above the water. But if you press the rubber sheet down, it will sink into the water. When you remove the pressure on the rubber sheet it will rise to the surface again.

This is because, when the rubber sheet is pressed, the air in the jar gets compressed. This increases the pressure on the surface of the water. This pressure is transmitted to every point in the water. Now the increase in the pressure in the water compresses the air in the doll and water enters the doll through the hole in the foot. This increases the weight of the doll and it sinks. When the pressure on the rubber sheet is removed, the pressure on the surface of the water is removed. The air in the doll returns to its original volume pushing out the water. The doll becomes lighter and rises to the original level.

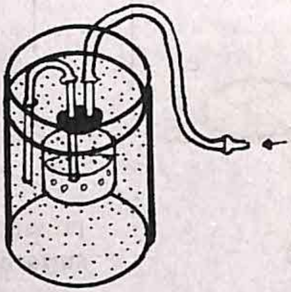
Submarines use the same principles to go under the sea and rise to the surface.

3.5 Atmospheric pressure

Gases share the fluid properties of liquids, like transmission of pressure and buoyancy, but, unlike liquids, gases have no definite volume. The density of gases is also very low compared to liquids. A column of air, a metre high, will

Activity 11 : *To see how a submarine is raised or lowered:*

Place pieces of iron or stones in the bottom of a small wide-mouth bottle and pour a little melted paraffin wax on them to fasten them down so that the bottle will float in an upright position. Insert a two-holed stopper. In one hole, place a U-shaped length of glass tubing which extends to the bottom of the bottle. In the other hole put a short length of glass tube. Join a rubber tube to this. Put the bottle in a vessel of water. Withdraw some air by sucking on the rubber tube and water will siphon into the bottle until the bottle sinks. The bottle may be made to rise by blowing out part of the water.



produce thrust at the bottom only 1/700, that of one metre column of water.

We live at the bottom of an ocean of air about 50 km high. Its pressure is quite high. It is useful to remember the pressure of the air that surrounds the earth (that is, the atmosphere) is equal to the pressure produced by a column of water ten metres high.

The atmosphere, or the envelope of air that surrounds the earth, is not of uniform density. As we go higher, the density of air decreases and so the atmospheric pressure also decreases.

Activity 12 : *Take a rectangular can. Pour a little water into it and boil the water with the top open. The water vapour will drive the air out of the can. Then close the mouth of the can with an airtight cap. The water vapour inside will condense, and you will observe that the can collapses as the pressure inside will be much less than the atmospheric pressure outside. Why does this happen?*

Activity 13 : *A drinking straw is filled with liquid. Place a finger over both ends and hold the straw vertical. When you take your finger off the bottom, the liquid stays in the tube. Why?*

Activity 14: *If a piece of cotton wool or cloth is wedged in the bottom of a tumbler and the tumbler is pushed down below the surface of water in a deep bucket, the cotton wool does not get wet. Why?*

MEASUREMENT OF ATMOSPHERIC PRESSURE

Atmospheric pressure was first measured by an Italian physicist Evangelista Torricelli (1608-1647) in 1644. He used a simple barometer with mercury in it.

THE SIMPLE BAROMETER

To make a simple barometer, take a 1 metre long thick glass tube with a narrow bore. It should be closed at one end and open at the other. Fill it completely with mercury. Tap the tube to see that there are no air bubbles inside. Now close the top end with a finger and insert it carefully into a bowl of mercury so that the open end is immersed in the mercury. Slowly remove your finger.

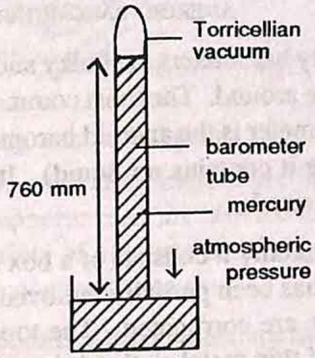


Fig. 3.13 The simple barometer

The mercury in the tube falls down slightly and settles at a certain level. Hold the tube vertically. The difference in the level of mercury in the tube and in the bowl gives the atmospheric pressure in terms of mercury column. Atmospheric pressure acting on the surface of mercury in the bowl supports the column of mercury in the tube. The space above this in the tube is called the *Torricellian vacuum* (Fig. 3.13).

ADVANTAGES OF USING MERCURY AS A BAROMETRIC LIQUID

i. It has a very high density (relative density) so, a 1 metre long tube is enough.

ii. It is opaque and its level can be easily observed.

iii. It does not wet glass. Mercury does not vapourise easily. So, the space above it in the tube is a true vacuum.

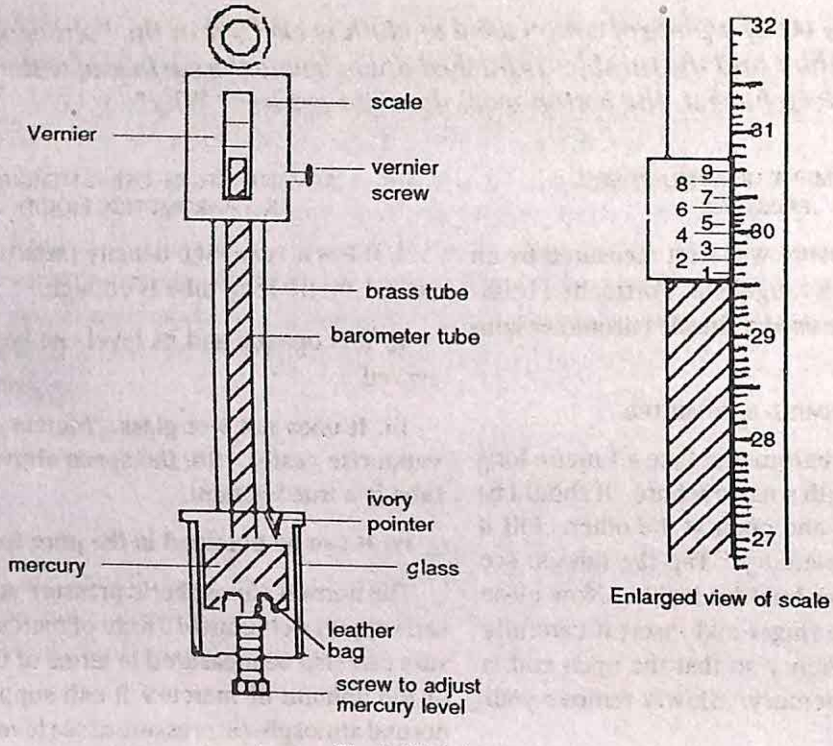
iv. It can be obtained in the pure form.

The normal atmospheric pressure at sea level can support a column of 76 cm of mercury. Pressure can also be measured in terms of the height of the column of mercury it can support. The normal atmospheric pressure at sea level is therefore 76 cm of mercury.

FORTIN'S BAROMETER

In the simple barometer it is necessary to take two readings . The level of mercury in the bowl or cistern and also the height of the mercury in the tube. In the Fortin's barometer only the level of mercury in the tube need be measured. The measurement in the simple barometer is a little difficult, time consuming and not very accurate.

Fortin's barometer (Fig. 3.14) consists of a vertical glass tube dipping into a cistern containing mercury. The upper part of the cistern is made of glass. The surface of the mercury can be seen through it. The cistern has a leather bottom which can be raised or lowered by a screw. A small ivory pin is fixed to the top of the cistern. The surface of the mercury in the cistern can be adjusted by raising or lowering the screw till the mercury touches the ivory point. The ivory point coincides with the zero of the vertical scale on the glass tube. So, the reading of the level of the



Enlarged view of scale

Fig. 3.14 Fortin's barometer

mercury column in the tube alone is enough.

The scale is graduated for convenience only from 68 cm to 81 cm and 27 inches to 32 inches. For the reading to be accurate, a vernier is attached to the barometer which can be moved up and down in a slot in front of the tube. While taking a reading, the vernier is raised up and down, till the top of the convex surface of mercury is on a level with the line of sight. This avoids any parallax error in the reading.

To take an accurate reading :

1. Raise or lower the screw operating the leather bottom till the surface of mercury in the cistern just touches the ivory point.

2. Take the reading using the main scale and the vernier. A reading upto the second decimal place of a cm can be obtained.

ANEROID BAROMETER

Mercury barometers are bulky and inconvenient to move around. The most commonly used type of barometer is the aneroid barometer (so called because it contains no liquid). It can even be pocket sized.

Essentially it consists of a box *A* from which the air has been partially removed. The ends of this box are corrugated. The top of the box is made of thin metal so that it is sensitive to even

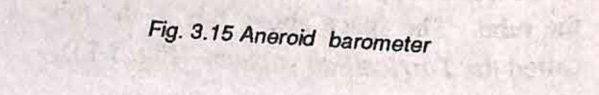


Fig. 3.15 Aneroid barometer

small changes in pressure. This small movement of the top of the box is magnified by a set of levers and causes a pointer to move along a circular scale (Fig. 3.15). The scale is graduated using a good mercury barometer.

THE BAROGRAPH

The barograph is a modified form of the aneroid barometer (Fig.3.16). This instrument is provided with an index which holds a pen at its outer end. The pen rests on a chart paper which is carried on a drum turned by clockwork. By this means the pen makes a complete tracing and the writing shows the changing atmospheric pressure during a whole week.

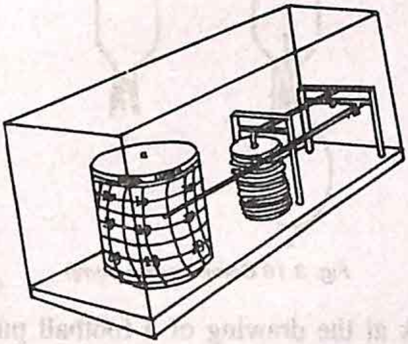


Fig. 3.16 The barograph

Uses of barometers: Barometers are used to measure atmospheric pressure. Hence they are useful for a variety of purposes involving measurement of atmospheric pressure.

i. In the laboratory barometers are most important. For many experiments in physics and chemistry, the correct atmospheric pressure must be known.

ii. Measurement of atmospheric pressure is needed for weather forecasts. If air contains more water vapour, the pressure is less. (Water vapour is lighter than air.) A low reading on the barometer usually predicts the coming of rain. Meteorologists (scientists who study the earth's atmosphere and the weather) gather barometer readings of atmospheric pressure from different places. The readings are plotted on a map. Places having the same pressure are joined on these maps by lines called *isobars*. From isobar maps of successive days, meteorologists will be able to predict which way low pressure regions are moving, and from that the possible weather conditions in various places also.

iii. As we go higher and higher the air becomes thinner. So, the atmospheric pressure also falls. For every 108 metres above sea level, the atmospheric pressure decreases by about 1 cm of mercury. Hence, if we know the atmospheric pressure at a place, we can estimate the height of the place above sea level.

Barometres used for estimating heights are called *altimeters.* The altimeter is a form of aneroid barometer. Altimeters are used in aircrafts to estimate heights. It is marked directly in metres instead of pressure.

Appliances based on air pressure

THE AIR PUMP

Air pumps are of two kinds:

1.the exhaust pump or the vacuum pump, and
2.the compression pump.

THE EXHAUST AIR PUMP

Figure 3.17 shows a simple exhaust pump. It consists of a cylinder *(B)* in which an air-tight piston *(P)* moves. The piston has a valve *(PV)* opening outwards. At the bottom of the cylinder there is another valve *(RV)* which also opens outwards. A nozzle *(T)* connects the pump to a vessel *(R)* from which the air has to be removed.

Let us suppose that the piston is at the lower end of the cylinder. When it is raised, the space between the valve *RV* and the piston increases. The pressure in this area decreases. The air from the vessel *(R)* pushes up the valve and enters the cylinder. Air from the vessel passes into the cylinder till the pressure is equal in both.

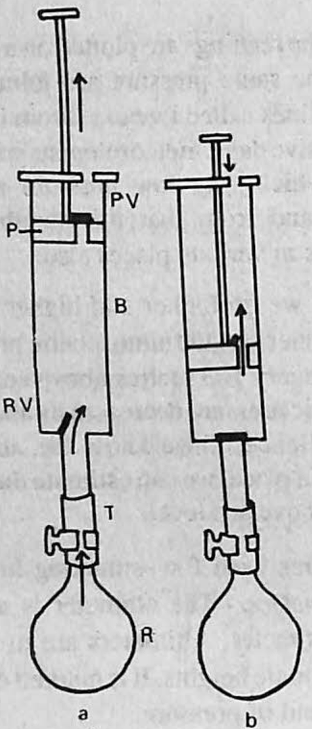


Fig. 3.17 A simple exhaust pump

Now, when the piston is pushed down, the air which has entered the cylinder is pushed out through the valve at the top *(PV)*.

Thus, with every upward stroke of the piston, some air comes out of the vessel. With every downward stroke that air is pushed out.

A perfect vacuum cannot be created by this pump.

a) The valves cannot open unless there is a minimum pressure in the vessel *(R)*.

b) There is always some leakage in the valve.

c) There is some dead space between the piston and the bottom of the cylinder.

A vacuum pump has many uses. The air from the metal box of an aneroid barometer is pumped out using a vacuum pump. In the thermos flask there is a vacuum between the two glass walls. This is also made using a vacuum pump.

THE COMPRESSION PUMP

A pump which is used for compressing air is called a compression pump. The common football pump and the bicycle pump are simple compression pumps.

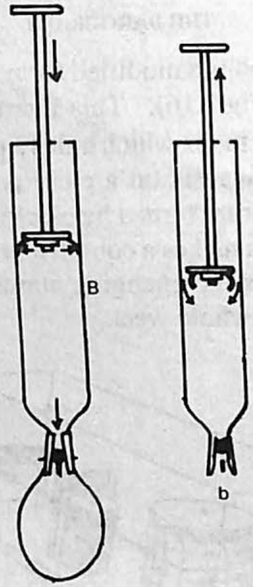


Fig. 3.18 Compression pump

Look at the drawing of a football pump in Fig.3.18. There is a cylinder *(B)* in which a piston can move up and down. At the end of the piston there is a cup-shaped piece of leather. This piece of leather is fastened to the piston rod by a piece of metal and a screw. The leather cup fits the cylinder firmly.

At the bottom of the cylinder there is a tapering nozzle. A metal ball just small enough is put into the nozzle. The open end has a small metal plate to prevent the metal ball from falling out. When the ball moves up, it closes the nozzle. We call such an arrangement a ball-valve.

When the piston is pushed down, the air below is compressed. The compressed air cannot go out through the upper end of the cylinder because the leather washer expands. The ball-valve in the nozzle allows the compressed air to be pushed into the football.

When the piston is drawn up, the leather washer moves downwards allowing air to fill the cylinder. At the same time the ball valve moves up the upper end of the nozzle preventing air from the football going back into the pump. Now we can begin the downward stroke once again.

You will notice that the leather washer is not only the head of the piston but also acts like a valve.

THE BICYCLE PUMP

The bicycle pump (Fig. 3.19) is the same as a football pump except that it does not have the ball-valve. The valve is not in the pump but in the cycle tube. The action of the pump is otherwise the same as that of the football pump.

The compression pump and compressed air have many uses. The compressed air in cycle tyres and automobile tyres makes riding comfortable. The pumps used to spray paint, insecticides, perfumes and other things also use compressed air. The pressure kerosene stoves used in homes and the bunsen burners used in the science laboratories have pressure pumps fitted in them. Compressed air is used to drive tools for cutting and drilling. Drills used for sinking bore wells use compressed air. Air brakes in trains and trucks use compressed air. In petrol pumps you can see compressed air being used to inflate automobile tyres.

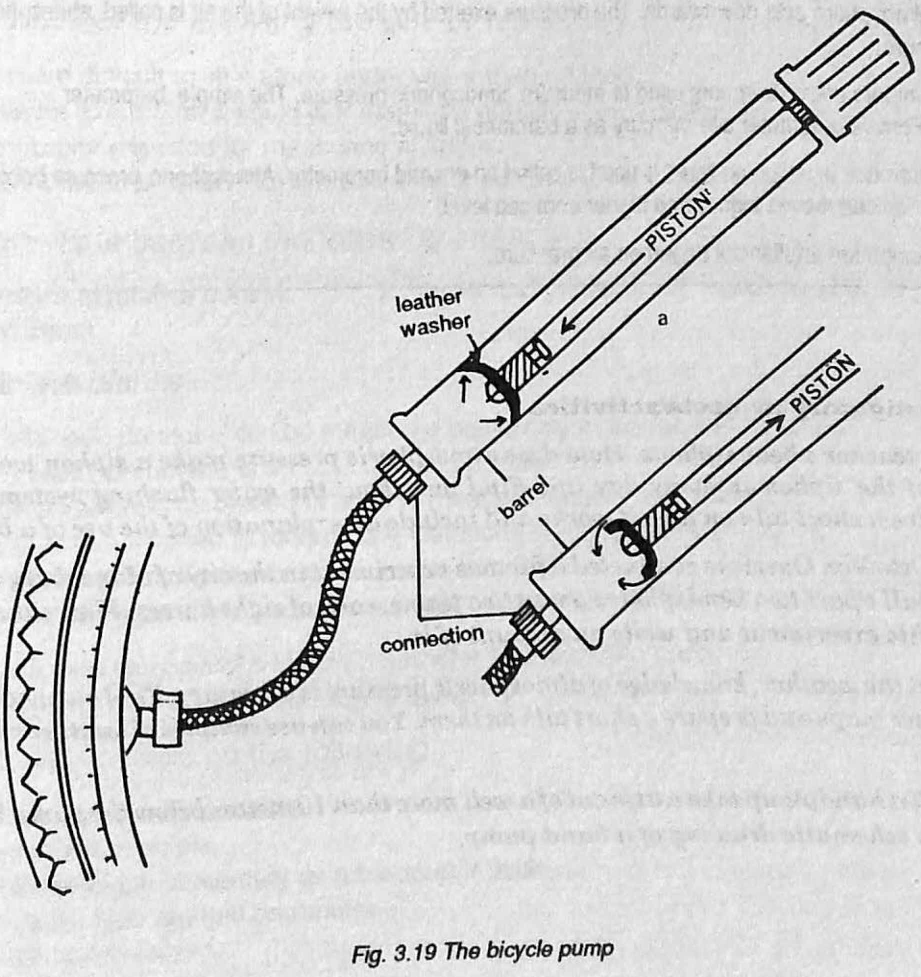


Fig. 3.19 The bicycle pump

Basic concepts

1. Relative density or specific gravity of a body is the ratio of the density of the body to the density of water. Relative density has no units.
2. Pressure is thrust or force per unit volume, and is expressed in pascal units.
3. Fluids have no regular shape and may be liquids or gases.
4. The pressure exerted by a liquid at a point depends on its density and the height of liquid above it.
5. A pressure applied at one point in a liquid is transmitted equally to every other point in the liquid.
6. Liquids find their own level.
7. When a body is wholly or partly immersed in a liquid, it has an apparent loss of weight equal to the weight of the liquid displaced by it.
8. The earth is surrounded by a jacket of air which is called the atmosphere. The weight of the atmosphere acts downwards. The pressure exerted by the weight of the air is called atmospheric pressure.
9. Barometers are instruments used to measure atmospheric pressure. The simple barometer and Fortin's barometer use mercury as a barometric liquid.
10. A barometer in which no liquid is used is called an aneroid barometer. Atmospheric pressure becomes lower as one moves higher and higher from sea level.
11. Air pumps are appliances based on air pressure.

Some investigatory projects/activities

1. Ask your teacher about siphons. How does atmospheric pressure make a siphon work ? List some uses of the siphon in every day life. Find out about the water flushing system in your lavatory. Give a short talk on how it works and include an explanation of the use of a ball-cock.

2. In 1657 Otto Von Guericke conducted a famous experiment in the city of Magdeburg in which he tried to pull apart two hemispheres using two teams, each of eight horses. Find out what you can about this experiment and write an account of it.

3. To predict the weather, knowledge of atmospheric pressure is necessary. Find out what you can about weather maps and prepare a short talk on them. You can use samples of weather maps from newspapers.

4. Why can't a handpump take water out of a well more than 10 metres below the pump ? Observe and make a schematic drawing of a hand pump.

REVISION TIME

1. *Choose the correct answer.*

A. If the density of a substance is more than that of water, its specific gravity is

i. less than 1. ii. greater than 1. iii. equal to 1.

B. When two solids of equal volume but different weights are immersed in water

i. they will displace different weights of water. ii. they will lose the same weight.
iii. they will have the same weight in water. iv. the heavier object will lose more weight.

C. A barometric pressure of one atmosphere may be expressed as

i. 13.6 gm per cc. ii. 29.92 inches. iii. 76 cm of mercury.

D. Water rises in the cylinder of a lift pump when the piston is raised because

i. water seeks its own level. ii. the air pressure in the cylinder is reduced.
iii. the water is pushed up due to atmospheric pressure.

II. *State whether the following are true or false :*

1. It is more difficult to lift a stone under water than on land.
2. Pressure exerted on a liquid is transmitted equally in all directions.
3. Barographs are used for measuring altitudes.
4. If a barometer is taken to the top of a mountain, the level of mercury rises.

III. *Differentiate between the following pairs:*

1. density and relative density. 2. thrust and pressure. 3. weight and buoyant force or upward thrust.

IV. *Fill in the blanks.*

1. Atmospheric pressure can be measured accurately in the laboratory using ....
2. A 'no liquid' barometer is an .... barometer.
3. When an aneroid barometer is used to measure heights it is called................................ .
4. A ....is used to record daily variations in atmospheric pressure.
5. The space above the mercury barometer is called ....
6. Atmospheric pressure .... as we go from plains to the hills.

V. 1. Draw a neat diagram of a simple barometer and mark the parts.
2. Draw and label the parts of a bicycle pump.

VI. Write short notes on the following :

1. Pascals law of fluid pressure.
2. Archimedes principle.
3. The advantages of mercury as a barometer liquid
4. The uses of the aneroid barometer.
5. Altitude and pressure.

Problems

1. A density bottle weighs 14.5 gm when empty, 39.5 gm when full of water, and 34.8 gm when full of spirit. Find the relative density of spirit. (Ans: 0.812)
2. A specific gravity bottle weighed 24.2 gm when empty, 39.74 gm when filled with water and 44.15 gm when filled with a solution of common salt. What is the specific gravity of the salt solution? (Ans: 1.28)
3. A girl of mass 45 kg is sitting on a wooden crate. If the area of the bottom of the crate is 0.5 square metres, what pressure does the girl exert on the ground ? (Ans: 90 kg/mt^2)
4. If the atmospheric pressure is 10 N/cm^2, what will be the total force due to the atmosphere on the flat roof which measures 12 m x 9 m. (Ans: .108 N)
5. A piece of wood weighs 100 gm in air, 60 gm in water and 50 gm in a solution of copper sulphate. Density of water is 1.0 gm/cc. Find (a) the volume of the piece of wood (b) the density of the piece of wood and (c) the density of the copper sulphate solution. (Ans: a) 40 cc b) 2.5 gm/cc c) 1.25 gm/cc.
6. In a Bramah press, the smaller piston has an area of 1 sq.m. and the larger piston an area of 5 sq.m. How much weight can be raised on the larger piston by a force of 100 kg. on the smaller piston? (Ans: 20 kg)

VII. *Write detailed answers.*

1. State Archimedes principle. How can you experimentally verify the principle ?
2. Describe the working of the Cartesian diver. What principles of fluids is demonstrated by it ? Name some modern equipment which works on the same principle.
3. Describe the construction and working of an exhaust pump.
4. State Pascal's law and describe how it operates in the Bramah press.

VIII. Give scientific reasons:

1. Why can't a simple lift pump take water out of a well more than 10 m below the pump ?
2. Why does a skin diver needs to wear only a 'wet suit', while a deep sea diver has to wear a thick head gear and protective clothing ?
3. Why does a ship sink deeper when it sails from the sea into the river?

4. Heat

Apparent expansion of liquids - anomalous expansion of water - heat and internal energy - measurement of heat - specific heat - change of state - thermostat.

You know that heat is a form of energy and that when bodies gain heat energy they become hotter, and when bodies lose heat energy they become colder. How hot or cold a body is, is known as its temperature and is measured using thermometers.

We shall learn some more things about heat in this chapter. Let us have another look at a fact you already know — that liquids expand in volume when heated.

4.1 Apparent expansion of liquids

You already know that when bodies gain heat energy their temperatures rise. When the temperatures of bodies rise they increase in volume. You may have done experiments to see how the length of solids increase when their temperature rises.

The volume of liquids, too, increase when their temperatures rise. How is the increase in the volume of a liquid for a certain increase in its temperature measured? Since a liquid has no shape, it can be heated only in a container.

When we heat a liquid in a vessel, the vessel also expands. Therefore the initial increase in volume is not the real expansion of the liquid. Without considering the expansion of the container, if we measure the expansion of the liquid, it will be an *apparent expansion*. When we calculate the expansion of a liquid after accounting for the expansion of the container also, we are measuring the *real* or *absolute* expansion of the liquid.

The expansion of a liquid when it is heated in a vessel is always the result of two effects — the real or *absolute* expansion of the liquid itself and the expansion of the vessel containing the liquid. Therefore, in the case of a liquid, there are two coefficients of expansion, i.e.,

1) The *absolute coefficient of expansion* (the actual increase in unit volume of a given liquid for unit increase in its temperature).

2) The *apparent coefficient of expansion* (the increase in unit volume of a given liquid, without taking into account the increase in the volume of the container, for unit increase in temperature). How can we measure the apparent and real expansion of a liquid?

Take a bulb and graduated tube arrangement as in Fig. 4.1. Fill it with a liquid upto mark *B* in the graduated tube. Immerse the bulb for a moment in a vessel containing hot water. You will notice a sudden fall in the level of the liquid in the tube from *B* to *A*. This is due to the expansion of the container which is the bulb . (The vessel containing the liquid gets heated before the liquid in it does.) Now, the volume *BA* in the graduated tube is the increase in the internal volume of the container or bulb.

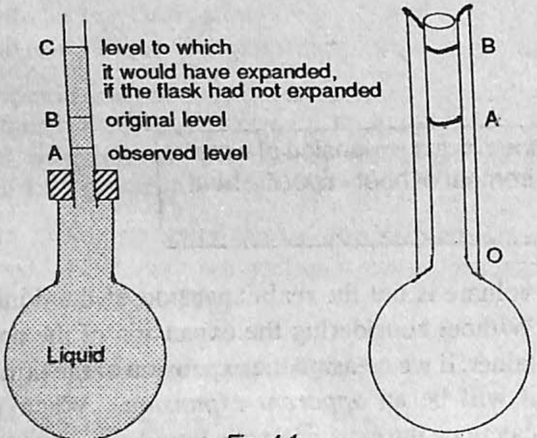

C
level to which it would have expanded, if the flask had not expanded
B
original level
A
observed level
Liquid
B
A
O

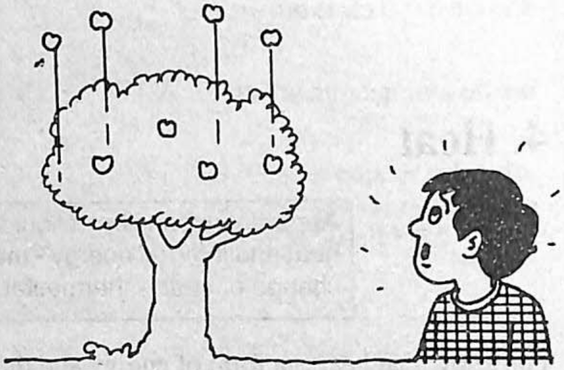
Fig. 4.1

After noting down the points *A* and *B*, immerse the bulb once more in hot water of the same temperature as the one used previously. Keep the bulb immersed in the hot water till the level of the liquid rises to a point *C* in the graduated tube and remains steady there. The volume BC on the graduated tube is the apparent expansion of the liquid. Now, we know that the real or absolute expansion of the liquid is the apparent expansion plus the expansion in the internal volume of the vessel containing the liquid.

In this case, the absolute expansion of the liquid *(AC)* = the apparent expansion of the liquid *(BC)* + the expansion of the vessel containing the liquid *(BA)*.

4.2 The curious behaviour of water (anomalous expansion of water)

Apples usually fall down to the earth from apple trees. Suppose there is an imaginary apple tree from which the apples do not fall downwards but go upwards to the sky. We would say that the apples from this imaginary tree behave curiously. They do not behave as apples normally do. Scientifically we would say that the behaviour of the apples from the imaginary tree is *anomalous*, or unusual.



Of course, there is no such apple tree in nature with apples that behave anomalously by 'falling' upwards instead of downwards. But there are often things which (under particular conditions) behave in unexpected and unusual or anomalous ways. Water is one such thing. We must understand the anomalous behaviour of water because it is very important to man and other living things.

All liquids, we know increase in volume when the temperature increases and decrease in volume when the temperature decreases. But water behaves anomalously or curiously in this matter. If we take some water at 0°C and heat it, we will notice the following :

1) Till 4°C the water will decrease in volume.

2) After 4°C the water will, like all other liquids, increase in volume (i.e., it ceases to behave anomalously or curiously above 4°C).

Since a given body of water will have the least volume at 4°C, we can see that water has maximum density at 4°C.

Now, if some water at 4°C is cooled, we will notice that (unlike other liquids) it increases in volume.

So, water at 4°C increases in volume whether it is cooled or heated. This curious behaviour of water is called the anomalous expansion of water.

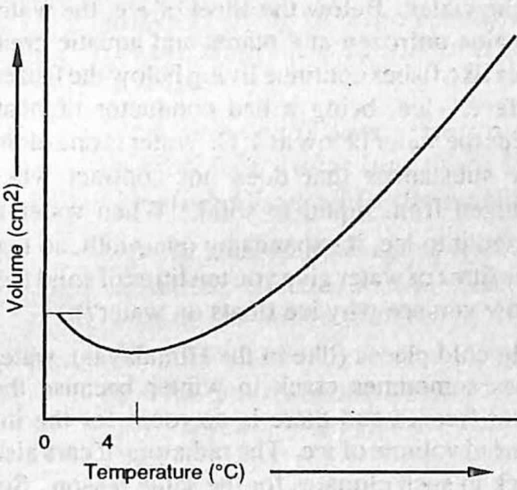


Fig. 4.2 Anamalous expansion of water

If we draw a graph between temperature and volume for a given mass of water, we will get a curve as in Fig. 4.2. From the graph we see that the given mass of water will have least volume (and therefore, maximum density) at 4°C.

VERIFYING THE ANOMALOUS EXPANSION OF WATER.

We can study the curious behaviour of water at 4°C in the laboratory. For this, we use an apparatus called Hope's apparatus.

The Hope's apparatus (Fig. 4.3) consists of a glass jar containing water. In the middle, the jar is surrounded by a jacket containing a mixture of ice and salt. The jar carries two thermometers,. one above the jacket and one below the jacket.

The freezing mixture in the jacket cools the water in the jar. The cooler water being denser, sinks to the bottom. The thermometer in the bottom of the jar shows a rapid fall in temperature, while the thermometer on top remains steady or shows a small fall. This goes on till the lower thermometer shows a reading of 4°C, at which it remains steady.

When all the water in the lower half has reached a temperature of 4°C, the water in the middle gets cooled below 4°C, and being lighter, rises up. From this point onwards the upper thermometer will begin to show a fall in temperature till it reaches 0°C. (The lower thermometer will remain steady at 4°C.)

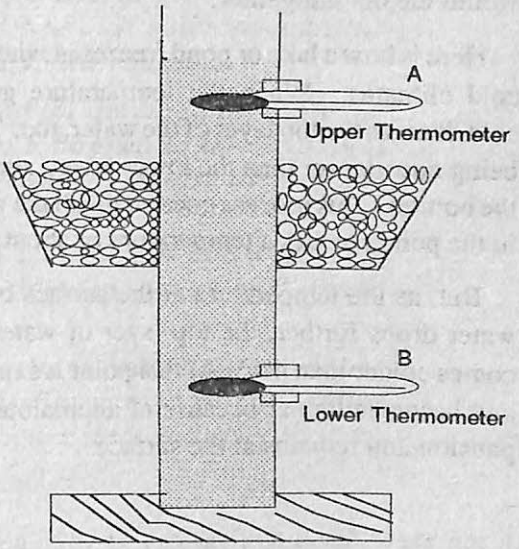


Fig. 4.3 Hope's apparatus

Ice will now begin to form in the middle and will float to the top of the jar. But the lower thermometer will continue to show a temperature of 4°C. This confirms that water has maximum density at 4°C.

NATURE AND THE ANOMALOUS EXPANSION OF WATER

The anomalous expansion of water is of great importance in nature. You have seen pictures of frozen lakes and ponds. You may have also seen arctic seas covered with large masses of ice in pictures or on television . This happens in the cold parts of the world during winters. Even when natural bodies of water are frozen, animal and plant life continues below the surface. This is possible because of the anomalous expansion of water.

Due to the anomalous behaviour of water at 4°C, ponds, rivers and lakes and the cold polar seas freeze from the top down. If they, instead, froze from 'bottom up' like other liquids, many important things about our life would be quite different. Not only would it change the climate of the world, but certain creatures that live in water would die out altogether.

Here is how a lake or pond freezes in winter in cold climates. When the temperature grows cold, it cools the top layer of the water, too. This, being now denser than the lower layer, sinks to the bottom. This process goes on till all the water in the pond reaches a temperature of about 4°C.

But, as the temperature at the surface of the water drops further, the top layer of water becomes colder than 4°C . At this point it expands and becomes lighter because of anomalous expansion and remains at the surface.

(When the temperature at the surface reaches freezing point of water 0°C), tiny crystals of ice begin to form on the surface. As they join together a whole sheet of ice forms on the surface of the water. Below the sheet of ice, the water remains unfrozen and plants and aquatic creatures like fishes continue living below the frozen surface. Ice, being a bad conductor of heat, keeps the water below at 4°C. Water is one of the few substances that does not contract when changed from liquid to solid. When water is frozen into ice, it expands by one-ninth, so that nine litres of water give you ten litres of solid ice! (Now you see why ice floats on water?).

In cold places (like in the Himalayas), water pipes sometimes crack in winter because the water freezes and there is no room for the increased volume of ice. The radiators of cars also crack in such climates for the same reason. So, in very cold places anti-freeze liquids are added to the water in the radiator to lower the freezing point.

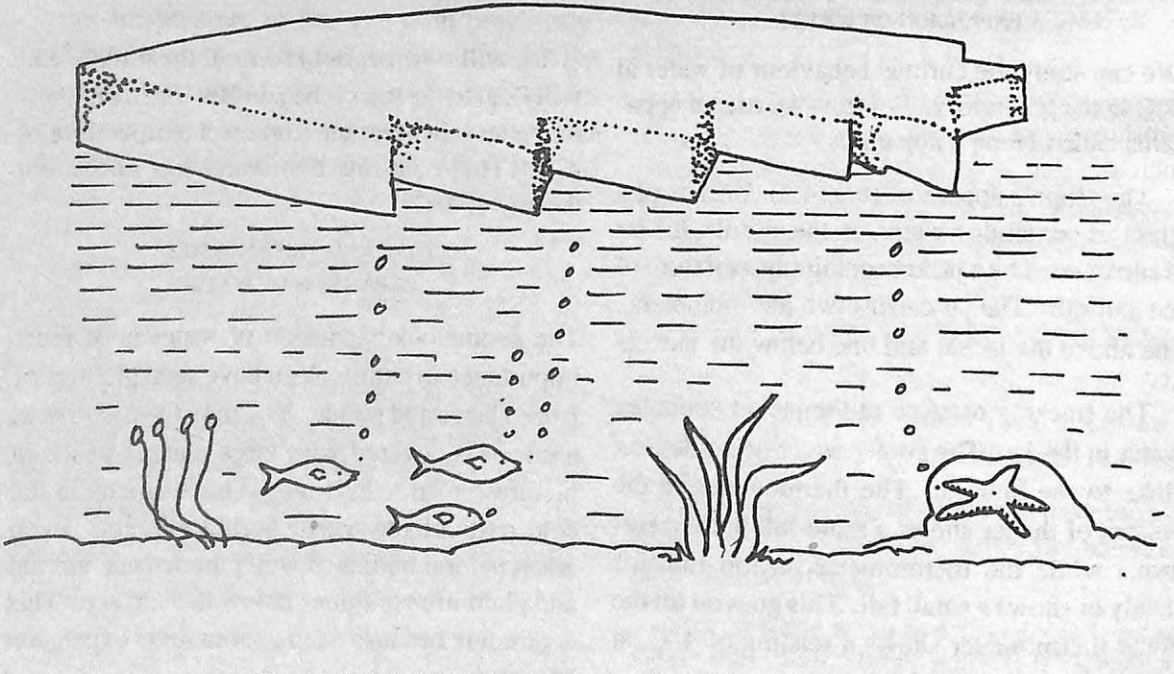


Fig. 4.4 Aquatic life survives even when the top layer of water freezes

Activity 1: *In the English Channel, the temperature of the sea water is close to 4°C during some periods of winter. At the same period, the temperature of the sea water in the equatorial region will be much higher. (Keep in mind the difference in density between the sea water in the English Channel and the seas close to the equator during the winter.)*

A ship loads to maximum capacity in a British port during this period (if it takes any more load it will sink). It sails through the English Channel to the warm seas close to the equator.

Using your knowledge of hydrostatics and the anomalous expansion of water, discuss in the class what would happen to the ship as it enters the warm waters from the near freezing waters of the English Channel.

2. Use your school library to find out all you can about Samuel Plimsoll and the Plimsoll line. Write a short essay about the Plimsoll line.

3. Watch on a video or film projection, Arctic or Antartic seas. Notice how the icebergs float on the water. Also observe how sea life continues below the frozen surface. Find out how Eskimos catch fish from below frozen water bodies.)

HEAT AND INTERNAL ENERGY

You know that all substances, whether solids, liquids or gases are made up of atoms and molecules. All molecules in a substance possess energy. Heat is a form of energy. So, when a substance gains heat, the energy of its molecules increases. It is important to know about the energy of the molecules of a substance to understand facts like boiling, melting, vapourisation, etc. Before that we must look at a *model of matter* which explains the energy of molecules.

A MODEL OF MATTER

We know that all substances are made up of molecules. All the molecules of a substance attract each other. This is known as *intermolecular attraction*. So, all substances have an energy of intermolecular attractions, which is the energy with which the various molecules attract each other.

Now, all the molecules of a substance have kinetic energy since they are constantly in motion. So, we can say that *a substance has a total internal energy made up of the total kinetic energy of the molecules and the energy of intermolecular attractions.*

Let us apply the model of matter to a gas. What happens when we heat a gas ? Since heat is a form of energy, the molecules of the gas gain more energy and so they move around more quickly. In other words, they gain kinetic energy. (Think of what would happen to the molecules if we cooled them instead of heating them.)

Let us imagine three molecules of the gas, *X*, *Y*, and Z. When the temperature of the gas increases, the kinetic energy of the molecules *X*, *Y* and *Z* increases. They move about more quickly in this agitated state. When the gas is cooled, the temperature is decreased and the kinetic energy of the molecules decreases. The cooler they become, the less they move around — the less kinetic energy they have. As the temperature decreases, a point will be reached when *X*, *Y* and *Z* are not moving at all. But before this happens, *X*, *Y*, *Z* and all the other molecules around them will first become a liquid and then a solid.

We can use the model of matter to represent what is happening in a liquid and in a solid as well as in a gas. This model of matter is also known as the *kinetic theory of matter*.

In a liquid, the molecules are closer together than in a gas. They can only move short distances before hitting another molecule. Unlike gases, liquids have a definite volume but no shape.

In a solid the molecules vibrate around a fixed position. The molecules of a solid also have a kinetic energy of vibration. But, they are not free to move around as in a liquid. So they have a definite shape.

THE KINETIC THEORY OF MATTER

1. All matter is made up of tiny parts of matter called molecules. Molecules are too small to be seen with ordinary microscopes.

2. The molecules are separated from each other by intermolecular space. The intermolecular space is most in gases and least in solids (the molecules are packed tightly in solids, less so in liquids and least in gases).

3. The molecules attract each other with a force called intermolecular force of attraction. This force is maximum in solids and minimum in gases.

4. The molecules of matter are in constant motion and so have kinetic energy.

5. The temperature of a substance is the measure of the average kinetic energy of its molecules.

We know that heat energy is required to raise the temperature of a substance. But the total heat content of a body is not the same as its temperature.

The heat content of a body is the total internal energy of the molecules of the body.

The temperature of a body is the measure of the average kinetic energy of the molecules of the body.

(The total internal energy of a substance is the sum of the total kinetic energy of its molecules and the total energy of its intermolecular attractions.)

4.4 The measurement of heat

The total heat content of a substance and its temperature are two different things. A cup of water at 90°C is much hotter (has a much higher temperature) than a large bucket, full of water at 50°C. But there is more total heat in the bucket of water. If both are allowed to stand for sometime, the cup of water will cool down to room temperature in a short time. During the same time, the bucket of water would hardly have cooled at all. The cup of water loses its heat more quickly because, among other things, it has much less heat than the bucket of water to lose.

You could say that heat is the cause and temperature is the effect.

UNITS OF HEAT

James P. Joule (1818-1889), an amateur physicist, proved that when a certain amount of work is done against friction, the same amount of heat is always produced. In the SI system, *energy* is measured in terms of the work it can do. That is, work and energy have the same unit. The unit is known as joules (J), which is the short form for *Joule's mechanical equivalent of heat*.

We mentioned that the unit of work and the unit of energy is the same in the SI system. One joule is the work done when a force of 1 newton moves through a distance of 1 metre in the direction of the force.

Though the SI unit of heat energy is Joules (J), the CGS unit of heat energy is still used commonly. In the CGS System, the unit of heat is *calories (cal)*. It is important to know the relation between the two units.

One calorie is the amount of heat required to raise the temperature of one gram of water through one degree Celsius . (You are perhaps aware, that Celsius is the same as Centigrade).

1000 calories make one kilocalorie. (The unit used to measure the energy content of food is also the calorie. This is the same as a kilocalorie and is spelt with a capital C. So don't confuse calorie with Calorie which is a thousand calories).

To come back to the SI unit of energy, Joules (J), 4.2 J of energy is required to raise the temperature of one gram of water through 1 °C.
Thus, 4.2 J = 1 cal
4200 J = 1 kilocalorie (or one Calorie).
Or 4200 Joules of heat energy is required to raise the temperature of 1 kg of water through 1 °C.

Now look at the table below which summarises the difference between heat energy and temperature.

Heat energy	*Temperature*
1. It is the total internal energy of the molecules that make up a substance.	1. The temperature of a substance is the measure of the average kinetic energy of the individual molecules of the substance.
2. It is measured in joules (J).	2. It is measured in degree Celsius (°C) or in Kelvin (K).
3. It indicates the energy needed to warm up an object.	3. It is not a measure of energy.
4. It is not helpful in deciding whether something is too hot to touch.	4. It is very helpful in deciding whether something is too hot to touch.

FACTORS AFFECTING HEAT ENERGY

Suppose we add heat energy to water, its temperature rises. Experiments show that the amount of heat required to raise the temperature of water by a fixed number of degrees varies with the mass of water receiving the heat.

Again, the quantity of heat required to raise the temperature of a fixed mass of water varies with the number of degrees Celsius by which the temperature is raised. It takes twice the amount of heat energy to raise the temperature of a given mass of water by 10°C than by 5°C.
(That is why the unit of heat is defined in terms of unit mass and unit rise in temperature. Actually, the quantity of heat required to raise the temperature of 1 kg of water by 1 °C also depends on the original temperature of the water. So, the original temperature must also be included in our definition of the unit of heat energy: 2400 joules or 1 kilocalorie is the amount of heat energy needed to raise the temperature of 1 kg of water from 14.5°C to 15.5°C).
What do these experiments show? Is it the amount of water, the temperature or both which affects the heat energy?

SPECIFIC HEAT

When the same mass of different substances are given the same amount of heat energy, some reach a higher temperature than others. some substances need more heat energy than others to raise their temperatures to the same degree. The measure is called the *specific heat capacity* of the substance. It shows how 'thirsty' a substance is for heat energy.

The specific heat capacity of a substance is the amount of heat energy required to raise the

Activity 4: *1. Take two beakers containing the same mass of water. Heat both to the same temperature. Note the temperatures. Pour the contents of one beaker into the other. Note the temperature now.*

Result : The temperature of 40 g of water is ____ °C.

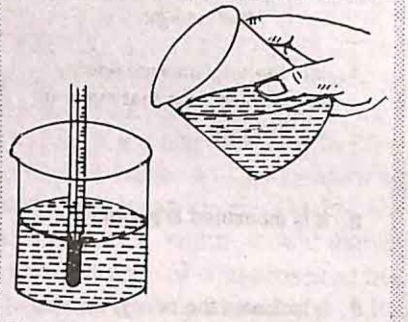
2. Take two beakers of water again containing equal masses of water but this time at different temperatures. Do the experiment as above. Note the temperature this time.

Result: The temperature of 40 g of water is ____ °C.

3. Take two beakers of water. This time each beaker should contain a different mass of water. Heat both to the same temperature and proceed as for the earlier two experiments. Note the temperature again.

Result: 60 g of water is at ____ °C.

Write under each diagram which beaker has more heat energy.



temperature of 1 kg of the material by 1°C. The specific heat capacity is measured in joules per kilogram per degree Celsius (J/kg/°C).

If we had 2 kg of the material we would need twice as much heat energy to raise the temperature by 1°C. Again, if we wanted to raise the temperature by 2°C, we would need twice as much heat energy again. We can, therefore write:

Heat energy =
mass x sp. heat capacity x temperature change ($t_2 - t_1$)

THERMAL CAPACITY

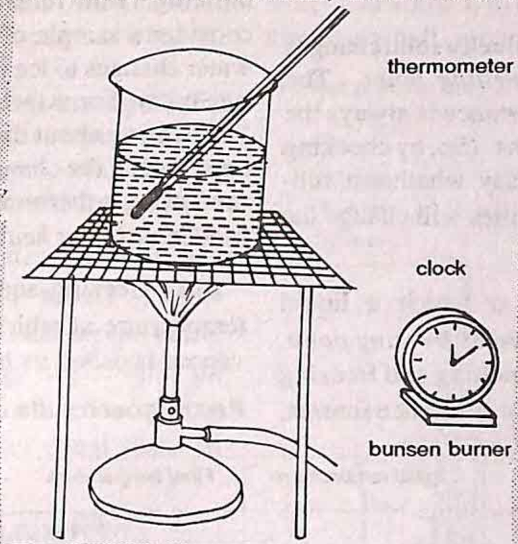
The amount of heat energy required to raise the temperature of a body through 1°C is known as its *thermal capacity* or *heat capacity*. The heat capacity of a body, as you can now see, will depend on its mass and specific heat capacity. Hence, thermal capacity = mass x sp. heat J/°C.

4.5 Change of state

You know that matter usually exists in three states — solid, liquid and gas. The most familiar example of a substance that exists in all three states is water — ice (solid), water (liquid) and water vapour or steam (gas).

If you take some ice in a beaker and put a thermometer in it, the reading will be 0°C. Now if you slowly heat the beaker you will see that the ice begins to melt and change to water. But the temperature will remain the same (0°C) until all

Activity 5 : *Heat some water for a fixed time (10 minutes would be convenient). Stir the water and measure the temperature change. Record your results in a table like the one below.*



Mass of water (kg)	*Initial Temperature (°C)*	*Temperature after (°C)*	*Temperature change (°C)*
$\frac{1}{2}$			
1			
$1\frac{1}{2}$			

Repeat the experiment with a new mass of water. Remember you are giving the same amount of heat energy to different masses of water.

Copy and complete this sentence :
When you give the same amount of ____ energy to different masses of ____, the greater the _____, the _____ is the temperature change.

Activity 6 : *How will the temperature change if we heat the same mass of different liquids?*
Heat $\frac{1}{2}$kg each of water, glycerol and oil. You can use the same apparatus as the last experiment, but stir the liquids well before reading the temperatures. Remember to heat each liquid for the same time. For the best results, all the liquids should have roughly the same initial temperature.

the ice has melted to water. After that the temperature will increase.

The fixed temperature at which a solid changes into a liquid is called its *melting point*. The melting point of a given substance is always the same under normal conditions. (So, by checking the melting point one can say whether a substance is pure or not. Impurities will change the melting point.)

The fixed temperature at which a liquid changes into a solid is known as *freezing point*. For a given substance, the melting and freezing points are the same. When a substance freezes, it loses heat and when it melts it gains heat, but the temperature remains the same. For example, consider a sample of water at 0°C. When that water changes to ice there is no drop in temperature but we know that some heat energy has been lost to bring about the change of state. The heat used during the change of state cannot be measured using a thermometer and so it is known as hidden or *latent heat*.

Like freezing and melting points, the fixed temperature at which a liquid changes into its vapour is called its *boiling point*.

Record your results in a table like the one below:

Liquid	*Mass*	*Initial temperature*	*Final temperature*	*Temperature change*
Water				
Glycerol				
Oil				

Describe how this experiment is different from the last one.

Did all the liquids receive the same heat energy? What does the experiment tell you about the specific heat capacity of oil and glycerol in comparison with the specific heat capacity of water?

SPECIFIC HEAT CAPACITY OF WATER

The following table gives you the specific heat capacity of a few commonly used substances.

Table of specific heat capacities

Substance	*Sp. heat in J / kg / °C*
Lead	130
Mercury	140
Brass	380
Copper	390
Iron	470
Aluminium	910
Glass	670
Iron	2100
Rubber	1890
Water	4200

You will notice that water has the highest specific heat capacity among the three liquids. Since the specific heat capacity of water is very high, it is extremely useful as a cooling agent (for example in the cooling system of automobiles). A hot water bottle will stay warm much longer if it is filled with water than with any other liquid. Oceans and lakes remain at a relatively stable range of temperature because water can absorb a lot of heat energy with only small changes in temperature.

Problem :

A block of copper has a mass of 200 g. It is heated from 20°C to 200°C. Calculate the amount of heat needed, if the specific heat capacity of copper is 420 J/kg/°C.

Mass of copper (m) = 200 g = 0.2 kg.
Temperature change $(t_2 - t_1) = 200 - 20 = 180°C$
Sp. heat capacity of copper (c) = 420 J/kg/°C
Total energy = m × c × dt
= .2 × 420 × 180
= 15,120 J

In the cycle of changes from solid to liquid and to gas (and the other way round) (i) there are points between two states when the temperature is the same,
(ii) when a substance changes state, the potential energy of its molecules change (because of gain or loss of latent heat), but their average kinetic energy or the temperature remains the same.

(Why is a burn caused by steam much worse than a burn caused by boiling water? This is because though they are at the same temperature, the steam has more heat energy to give up (i.e., the latent heat which it gained when boiling water became steam) than an equal mass of water).

DETERMINATION OF MELTING POINT

1. *Capillary tube method* : Take a small quantity of wax in a narrow capillary tube. Seal the tube at one end. Tie it to a thermometer (Fig. 4.5). Suspend these in a beaker of water and heat gently. Note the temperature at which the substance begins to melt. Now allow the water in the tube to cool. Note the temperature at which the liquid in the capillary tube begins to solidify. The average or mean of the two temperatures gives the melting point of the substance.

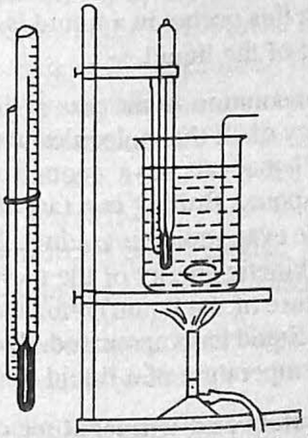


Fig. 4.5 Capillary tube method

Cooling method : Take some stearic acid in a test tube. Close the test tube with a one-holed-stopper. Insert a thermometer through it to touch the stearic acid crystals. Heat the test tube in a water bath until it melts. Remove the test tube from the water and allow it to cool. Record the temperature every half minute.

Put the results into a table like the one below :

Time	Temperature
1/2 min	
1 min	
1.5 min	

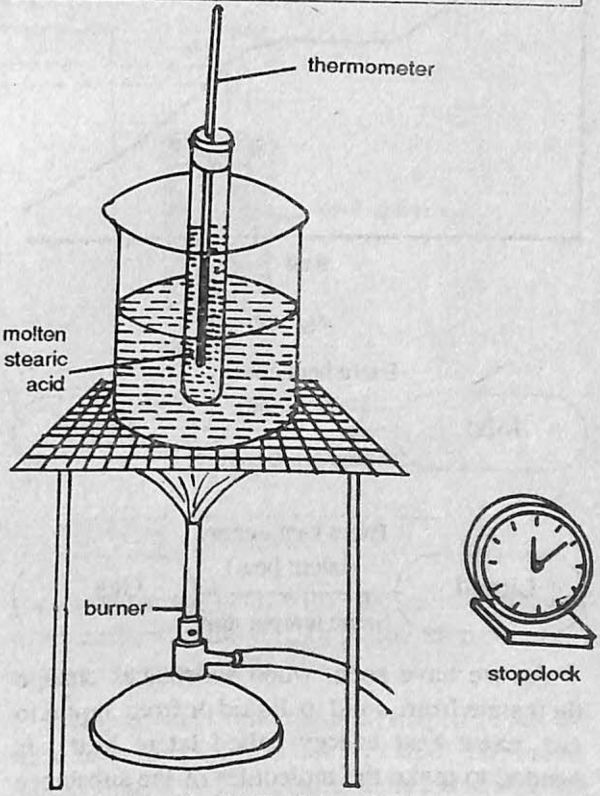


Fig. 4.6 Cooling method

Note the temperature at which the stearic acid becomes a solid. Continue recording till the temperature drops 20°C below this value.

Plot a graph of temperature against time from the data in the table you have made. What do you notice about this cooling curve?

The graph levels out for a period of time when the stearic acid turns from liquid to solid. We can explain this by considering the energy needed to change the state of a substance, that is, the latent heat energy.

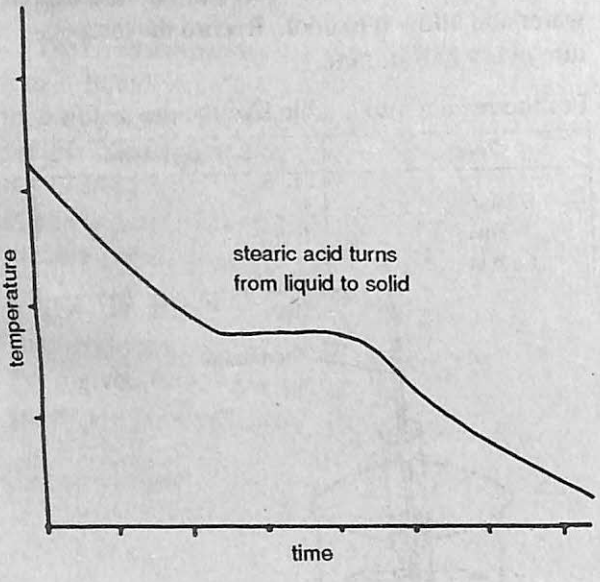
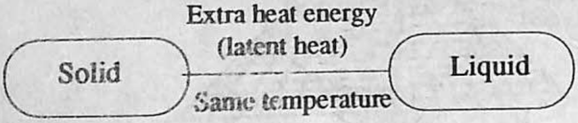
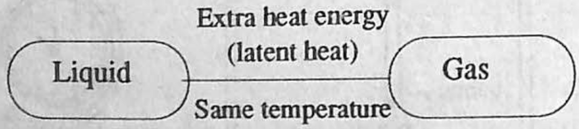


Fig. 4.7





As we have seen, when substances change their state from solid to liquid or from liquid to gas, extra heat energy called latent heat, is needed to make the molecules of the substance move apart and the change of state to take place.

However, when stearic acid changes from a liquid to a solid, it gives out heat energy (or loses latent heat). So, for a period of time the temperature stays constant while the stearic acid is becoming a solid, although the stearic acid is losing heat energy.

EVAPORATION AND BOILING

Water in a saucer if left open, vanishes after a few days as if by miracle. Spray some perfume on your hand and it soon dries and vanishes (even if the fragrance remains) leaving the spot in your hand colder. In both these cases you know that evaporation has taken place.

How does the kinetic theory explain evaporation? We know that at any given temperature the average kinetic energy of all the molecules is the same though some molecules may be moving faster than others.

During evaporation, molecules possessing more kinetic energy than the average energy of the other molecules escape from the surface of the liquid into the air above, and the less energetic ones are left behind. So, when a molecule evaporates it will have more energy. The kinetic energy of the molecules remaining in the liquid will therefore be reduced and so the temperature of the liquid will drop. Evaporation, thus causes cooling of a liquid (this principle is used in a refrigerator). The more surface area a liquid has, the more evaporation there will be. (Water spread on a sheet of glass will evaporate much faster than the same amount of water kept in a narrow drinking glass.)

When a liquid is heated, at first its temperature rises. Then it becomes constant and the liquid rapidly changes into its vapour at this constant temperature, i.e., it boils. The constant temperature at which this occurs in a liquid is called the boiling point of the liquid.

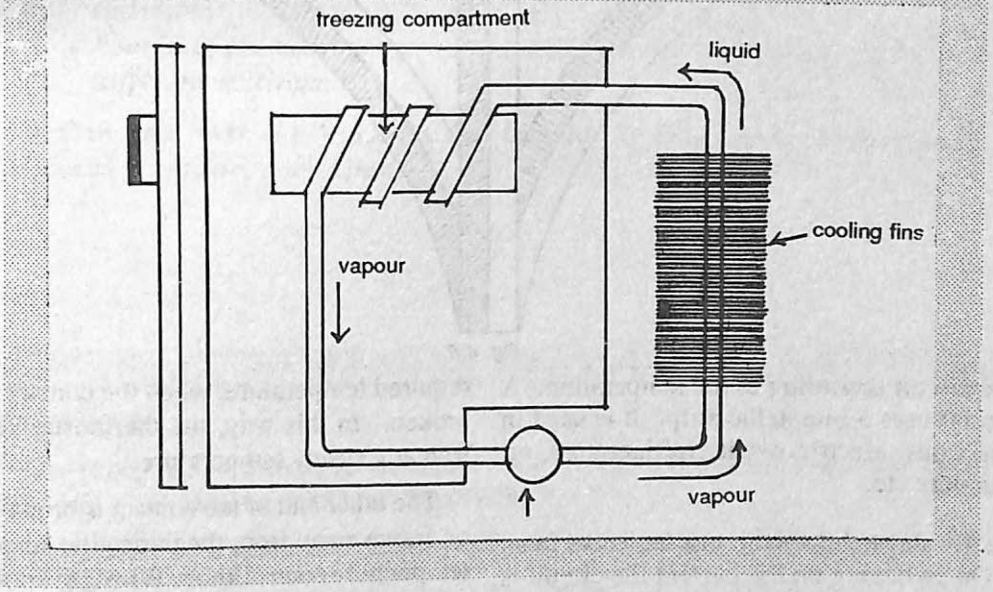
Unlike evaporation, in the case of boiling, the kinetic energy of all the molecules in a liquid is increased till they all have enough energy to escape as vapour. Boiling is a fast and violent process while evaporation is gradual. In boiling, the average kinetic energy of the molecules (or the temperature of the liquid) remains the same till all of the liquid has vapourised. Evaporation causes the temperature of a liquid to drop.

4.5 Thermostats and temperature control

The change in dimension with change of temperature is quite small in the case of solids and liquids, but there are simple methods of magnifying small changes in dimension.

Activity 7 : *Place two containers holding equal volumes of water at different temperatures in a freezer. What do you observe? Which sample of water freezes first? This happens because more of the hot water evaporates than the cold, leaving a smaller mass to freeze.*

Activity 8 : *Use this diagram to explain how a refrigerator works. It may help you to notice that in the tubing around the freezing compartment the liquid is constantly evaporating to form a vapour.*



One method is to weld strips of two different metals together, say a strip of brass with one of iron. Since the coefficient of linear expansion of brass is about double that of iron. Therefore, for a given change of temperature a brass strip will change in volume (and, therefore, in length) nearly twice as much as an iron strip of the same size. If the two strips were not welded together the iron and brass could change lengths with changes in temperature, independently.

What happens when the two strips of iron and brass are welded together?

In such a welded strip (strips of two metals of different coefficients of expansion welded together are known as *bimetallic strips* or *compound bars)*, the strips of the two metals cannot change in length independent of each other. Bimetallic strips bend with change in temperature to adjust to the different amount of expansion of the two metals.

In a brass and iron bimetallic strip, it bends in the direction of the iron if it is heated. The brass would then lie on the outside of the curve and the iron on the inside (Fig. 4. 8). Since the outer rim is longer than the inner, the brass strip's greater expansion in length is accommodated although the two strips are welded together.

As the temperature falls and returns to the original value, the strip becomes straight once again. If the temperature falls below this point, the strip will bend in the direction of the brass (brass contracts more than iron with falling temperature. Since brass is now on the inner side of the curve the greater decrease in length of brass is adjusted by the bending).

Such bimetallic strips can be used for various applications as a thermometer, to make compensation pendulums (pendulums which do not change in length with temperature changes), and also thermostats to control the temperature levels of various appliances like the electric iron and refrigerators.

THERMOSTATS

A thermostat is a device which can maintain a steady temperature by making and breaking an electric circuit according to the temperature. A thermostat uses a bimetallic strip. It is used in electric irons, electric ovens, refrigerators, air conditioners etc.

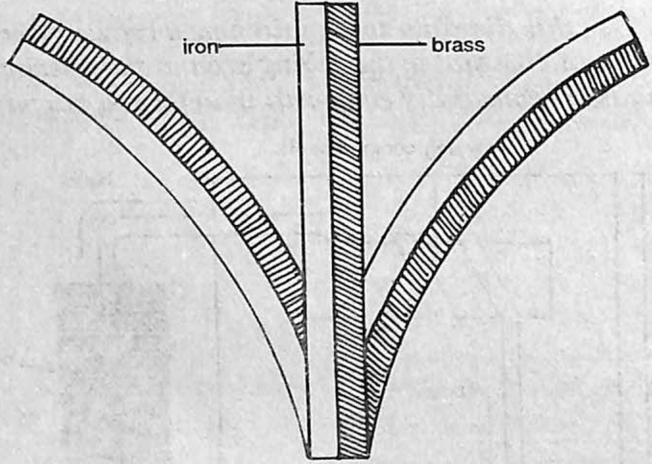


Fig. 4.8

Fig. 4.9 shows how a thermostat works in an iron. On switching on the current the circuit is completed as the two contacts touch each other. When the electric iron becomes hot the bimetallic strip bends away as explained earlier and the circuit is broken. The iron cools down. When it becomes cold the strip straightens out and contact is made. The iron becomes hot again to the required temperature, when the contact is again broken. In this way, the thermostat keeps the iron at a steady temperature.

The other end of the contact is brought closer or drawn away from the bimetallic strip using a temperature control knob. When the knob pushes the other end of the contact against the bimetallic strip to the maximum, the contact will not break till the iron reaches a very high temperature. If it is pressed to the bimetallic strip only to a minimum, the circuit will break at a lower temperature.

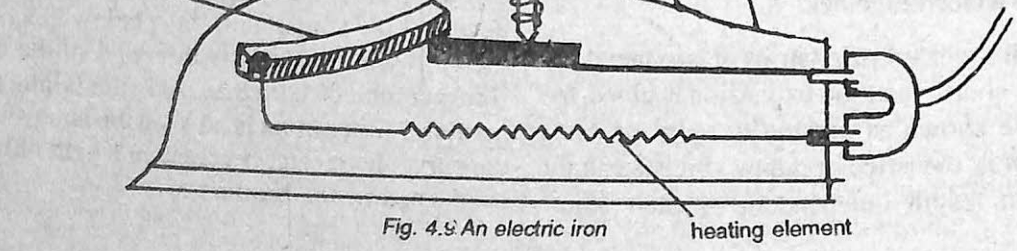


Fig. 4.9 An electric iron

Activity 9 : *A similar thermostat makes the compressor in your refrigerator come on and go off now and then. Note how often the refrigerator at home comes on and goes off, and for how long it works each time it comes on. Note : It also depends on which position you have kept the temperature control knob inside.*

Keep the refrigerator at different temperature settings using the temperature control knob inside. Observe

i. how often the compressor comes on and goes off at different settings.

ii. how long the compressor works each time before going off, for different settings.

Can you hear the 'click' as the bimetallic strip in the thermostat makes contact each time?

Basic concepts

1. The real or absolute expansion of the liquid is the sum of the apparent expansion and the expansion of the internal volume of the container.
2. At 4°C the volume of water will increase whether its temperature rises or falls.
3. Temperature is a measure of the average kinetic energy of individual molecules of a substance and heat is a measure of the total internal energy of the molecules of a substance.
4. One calorie is the amount of heat energy required to raise the temperature of one gm of water by 1°C.
5. In the SI system, energy and work have the same unit — the joule.
6. The specific heat capacity of a substance is the amount of heat energy required to raise the temperature of a unit mass of a substance 1 kg. through 1°C.
7. There are fixed points of temperature at which different substance change from one state to another (solid, liquid or gas).
8. A body gains latent heat when it changes from solid state to the liquid state and from the liquid to gas or vapour. A body loses latent heat when it changes from the gaseous state to liquid and from the liquid state to the solid state.
9. Evaporation is the change of state from liquid to gas at any temperature and boiling is the change of state from liquid to gas at a fixed temperature.
10. A thermostat is a device which can control temperature by automatically breaking and making an electric circuit.

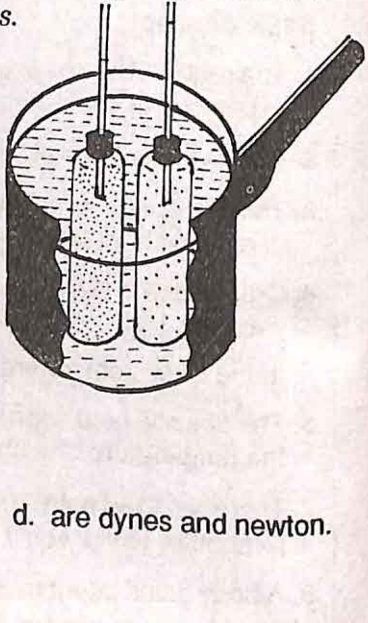
Some investigatory projects/activities

1. James P. Joule, from whose name we have our unit of work and energy, was most interested in turning other forms of energy into heat. Joule thought that as water fell from a high waterfall it would have a large amount of potential energy which would turn into kinetic energy. When the water hit the rocks at the bottom much of the kinetic energy would be turned into heat energy. So the water at the bottom of a waterfall should be a little warmer than water at the top.

It is said that during his honeymoon he tried to check out this fact. He took two accurate thermometers, gave one to his wife and sent her up the hillside to measure the temperature at the tip. Meanwhile he stayed at the bottom, measured the temperature there and ate his sandwiches! (Do you think Joule's guess was correct?)

2. Joule studied the relation between work and heat. Fifty years before Joules proved the relation between work and heat energy, a man named Count Rumford did some famous experiments to prove the same fact. He began his experiments at Munich where a cannon was being bored. Try to find the story of Count Rumford and the boring of the cannon, from books in your school library. What does this experiment prove?

3. Fit two or three similar medicine bottles with corks and tubes. Fill them with liquids of different viscosity and immerse them in a pan of hot water (see diagram). The rise inside the tubes will indicate the difference in expansion rates.



REVISION TIME

I. *Choose the correct answer*

1) Water at the bottom of a frozen lake will be ....
a. 0°C. b. 4°C. c. 32°C.

2) In the SI system, the unit of work and energy ....
a. are different. b. are inversely proportional. c. are the same. d. are dynes and newton.

3) Water has the maximum volume at ....
a. 273°C. b. 32°C. c. 4°C. d. 100°C.

4) Equal masses of two substances at the same temperature are taken. Then, the substance with higher specific heat capacity will have ....
a. more internal energy than the other. b. less internal energy than the other. c. the same internal energy as the other substance.

5) The specific heat capacity of a substance may be called its capacity for internal energy
a. Yes. b. No. c. only in the case of gases.

II. *Differentiate between the following pairs :*

1. apparent and absolute expansion of a liquid.
2. heat energy and temperature.
3. specific heat and heat capacity.
4. evaporation and boiling.

III. *Fill in the blanks.*

i. When 1 kg of water is heated from 14.5 degree C to 15.5 degree C, the amount of heat supplied in joules is ________ .

ii. The work done in order to raise the temperature of 1 gm of water by 1 degree C is ________ .

iii. The heat capacity of 2 kg of water is ________ joules.

v. Water has maximum density at ________ degree C.

vi. The unit of specific heat capacity is ________ .

IV. *Draw and mark the parts of a Hope's apparatus.*

V. *Write short answers for the following:*

1. Define calorie and kilocalorie.
2. Define heat energy and joule.
3. Define specific heat capacity. How many joules of heat energy are released when a piece of aluminium of mass 200 g cools from 60 to 50°C. The specific heat capacity of aluminium is 910 joules/kg/°C. (Ans: 1820 J.)
   (The temperature difference $t_2 - t_1$ will be negative showing that heat is lost, not gained. But since we are calculating the quantity of heat we do not consider the negative sign.)
4. What is the heat required to raise the temperature of 100 g of water in a copper vessel weighing 40 g from 15 degree C to 75 degree C? The specific heat of copper is 390 joules/kg/ °C and that of water is 4200 J/kg/°C. (Ans: 26136 joules)
5. What is meant by change of state? Define melting point of a substance.
6. What is meant by the internal energy of an object? Which possess more internal energy, a gram of water at boiling point or a gram of steam? Why?
7. What is a thermostat? What are its uses?

VI. *Write detailed answers for the following.*

i. Describe the capillary tube method of finding the melting point of wax.

ii. What is the anomalous expansion of water? How is this property of water important in nature.

iii. What is a bimetallic strip? Why does it curve when heated? Explain using a diagram.

VII. *Give scientific reasons for the following.*

i. Why are pieces of ice at 0°C added to a glass of lemonade (at room temperature) more effective in cooling it than an equal mass of water at 0°C?

ii. Why does wet cloth on a container cool the water inside?

iii. Sweating is a body mechanism used to bring down body temperature when it is overheated due to exertion or fever. How does sweating bring about a fall in body temperature?

5. Light

Reflection in plane mirrors - laws of reflection - uses of plane mirror - curved mirrors and their uses - refraction - lenses and their uses.

You are reading this because light is being reflected from the white area of the page, while it is absorbed by the black letters. Light is made up of little packets of energy which travel in the shape of waves. You have already learnt that light waves travel in straight lines. (In scientific language, we call this the 'rectilinear propagation of light'.)

Mirrors and highly polished surfaces reflect light strongly *in a particular direction*, and we will now learn about the nature of such reflections.

5.1 Reflection in a plane mirror

Bodies which do not allow light to pass through them are called opaque.

When a body is opaque, it may either absorb light falling on it or reflect it. If the surface of a body is uneven or rough, light waves falling on it get reflected in all directions (they are scattered).

A plane, polished surface reflects all the light in a particular direction. (Very little of the light that falls is scattered.) Such a smooth polished surface is a mirror.

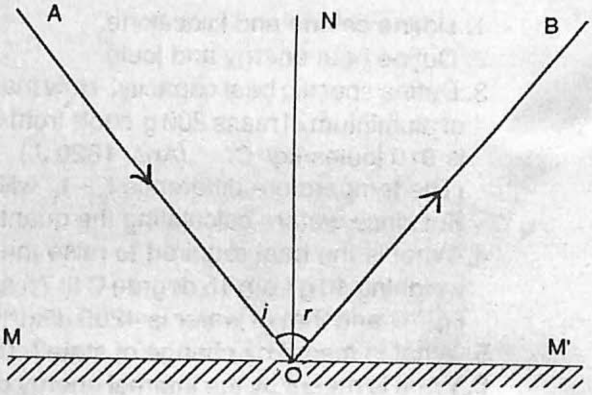


Fig. 5.1

Fig.5.1 illustrates the terms we use while studying reflected light. *MM '* represents the surface of a plane mirror. A beam of light falling on the reflecting surface of the mirror is known as the *incident ray*. In the figure it is represented by the line *AO*. *O* is the *point of incidence* or the point where the beam of light strikes the reflecting surface of the mirror.

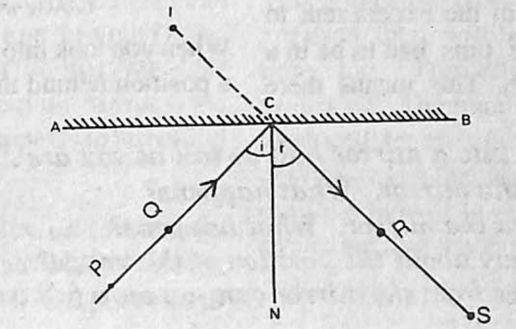
The beam of light which is reflected after striking the mirror is known as the *reflected ray*. The reflected ray is represented in the figure by the line *OB*.

ON represents the *normal* or perpendicular to the reflecting surface (in this case, the mirror) at the point of incidence.

The angle made by the incident ray with the normal to the mirror at the point of incidence is the angle of incidence ($\angle NOB$ or $\angle r$). The angle made by the reflected ray to the normal at the point of incidence is known as the *angle of reflection* ($\angle AON$ or $\angle i$).

Let us observe two important rules of reflection. The reflected light from the pin which falls on the mirror shall be the *incident ray*.

Activity 1: *Fix a sheet of white paper on a soft board. Draw a straight line AB on it. Place a mirror upright on this line. Fix two pins P and Q (about 5 cm apart) in front of the mirror so that the line joining the two pins will be at an angle to the surface of the mirror.*



Now, place your eye on the other side so that the images of P and Q are in a straight line, one behind the other. Fix two pins R and S so that they are in one straight line with the images of P and Q. Now remove the mirror and join PQ and RS to meet the line AB at O. Measure the angles PON and RON. Repeat the experiment for different inclinations of PQ. Note your observation in the tabular column below:

S.N	Angle of incidence	Angle of reflection
1		
2		
3		

We know, the line joining the two pins *P* and *Q*, represents an incident ray. The line joining *R* and *S* represents the reflected ray. The perpendicular *NO* to the mirror at the point of incidence *O*, is the normal.

You will notice that in all cases, the angle of reflection is equal to the angle of incidence. Also, that the incident ray, the reflected ray and the normal to the surface at the point of incidence lie on the same plane — that of the paper.

These are unchanging facts of reflection in a plane mirror. They are known as *the laws of reflection in a plane mirror*.

The laws of reflection in a plane mirror, therefore, are:

i. The angle of reflection is equal to the angle of incidence.

ii. The incident ray, the reflected ray and the normal to the surface at the point of incidence, all lie in the same plane.

LOCATING IMAGES BY NO - PARALLAX

When you used the pins in the experiment to trace the reflected ray, the pins had to be in a straight line with the image. This means there should be no parallax between the two pins and the image.

The method of 'no-parallax' is used when you are taking a reading on a scale or when you are locating the position of an image using pins. The pin is placed near the image and is moved about until both the pin and the image seem to coincide in the same straight line, at the same time as the eye is moved from side to side. In that position we say that there is no parallax. In the 'no-parallax' position, the pin gives the position of the image.

IMAGE IN A PLANE MIRROR

When you look into a mirror you see an image in a position behind the mirror.

Activity 2: *Look into a mirror half as tall as you are.*
Walk towards the mirror. What happens?
Walk away from the mirror. What happens?
What can you say about the position of the image?
At what distance from the mirror can you see a full length image of yourself?

Unlike the images we see on a cinema screen, (the images on a cinema screen are said to be *real*. They are formed by the actual projection of real rays of light.) the images we see in a mirror cannot be formed on a screen. Such images are said to be *virtual*. The virtual image in a plane mirror seems to be produced at the point where the reflected rays meet when they are produced backwards behind the mirror (Fig. 5.2).

The image in a plane mirror is the same size as the object. Another important thing to note is that in a mirror your left hand will appear to be your right. If you move your left hand the image in the plane mirror will appear to have its right hand moving. We call this effect *lateral inversion* (The word 'lateral' means 'sideways'.) (Fig.5.3). You may have noticed that words written on paper in ink appear *laterally inverted* on a blotting paper which has been used to dry the ink.

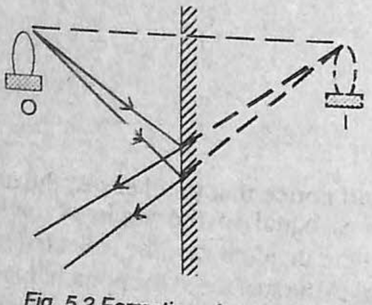


Fig. 5.2 Formation of a virtual image

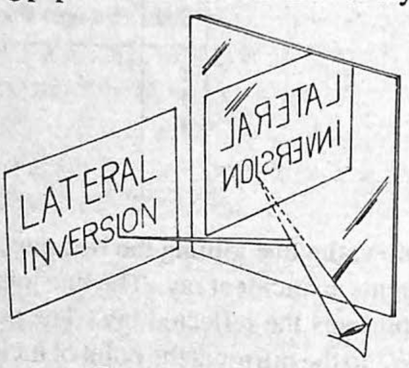


Fig. 5.3. Lateral inversion

It will appear the right way round if the blotter is held up in front of a plane mirror.

Let us consider how the eye sees an image in a plane mirror. Look once again at Fig. 5.2. It shows the reflection of a lamp in a plane mirror. The incident ray and the reflected ray is represented by lines with arrows showing the direction of the ray. The dotted lines show the *virtual* image and the path through which the reflected rays *appear* to be coming. (Such figures are called ray diagrams.)

We know that the position of the image *I* can be constructed by drawing a line through *O* perpendicular to the mirror at *M*, so that $OM = IM$ (the distance of the object from the mirror = the distance of the image which appears to be behind the mirror).

When looking into the mirror, the eye sees the image *I* apparently by the cone of rays coming from IE_1E_2 which enter the eye. The portion *IAB* of this cone of rays obviously does not exist. There is no light from behind the mirror.

The real portion ABE_1E_2 is the result of light travelling down the cone *OAB* and reflected from the mirror at *AB* according to the laws of reflection. The complete real cone of rays $OABE_1E_2$ is called the 'pencil' of light by which the eye sees the virtual image *I*.

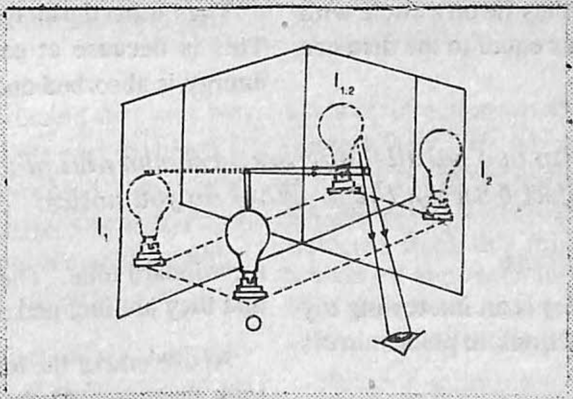
5.2 Uses of plane mirrors

One plane mirror usually gives one image of an object. How many images would you get if we placed an object between two plane mirrors? You will find that you get more than two images. This is because when two or more plane mirrors are used, there will be reflections of the reflections, too. This effect is known as *multiple reflection*. The number of images of an object produced by two mirrors will depend on the angle between the two mirrors. The principle of multiple images in plane mirrors is used in instruments like the kaleidoscope.

IMAGES FORMED IN TWO MIRRORS INCLINED AT 80°

When the angle between the two mirrors is 80°, you find four images in the two mirrors. Now, if

Activity 3: *Place a lamp in front of a plane mirror. Hold another mirror touching it , at an angle of about 80° . How many images do you see? Now reduce the angle between the mirrors gradually to 30°. Observe how the number of images change.*



you increase the angle between the two mirrors to 90°, two of the images come together and merge and we see three images in all (actually four images are formed, but two of them coincide and so only three are visible).

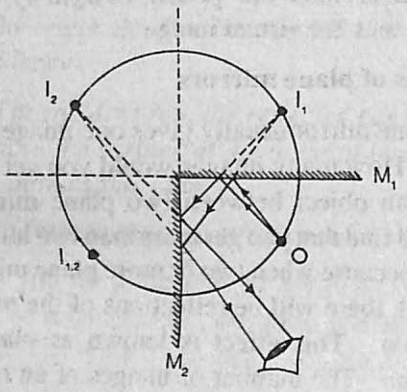


Fig. 5.4 Multiple reflection

Two of the images I_1 and I_2 (see Fig. 5.4) are formed in the two mirrors by reflection. The third one, $I_{1,2}$ is formed by double reflection (that is, the reflection of a reflection).

In the geometrical construction it is obvious that the three images and the object form a rectangle whose mid-point is P.

The third image, being laterally inverted twice, is not inverted with respect to the object.

The three images and the object are equidistant from the point of intersection(P) of the two mirrors. As you can see, they lie on a circle with P as the centre and radius equal to the distance of the object from P.

The number of images (n) formed by two plane mirrors inclined to each other are given by the formula :

number of images (n) $= \left(\dfrac{360}{\theta} - 1\right)$

where θ is the angle between the two mirrors.

PARALLEL MIRRORS

An infinite or endless number of images of an object are formed when it is placed between two parallel mirrors. All these lie on a straight line through the object perpendicular to the mirrors. (Fig. 5.5.)

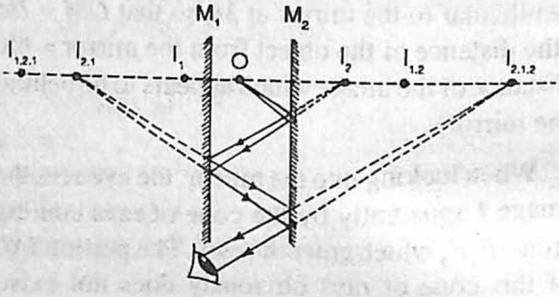


Fig. 5.5 Reflection in parallel mirrors

The positions of the images may be constructed by remembering that the image seen in one mirror will act as a virtual object and produce an image in the other mirror.

The farther the images the fainter they become. This is because at each reflection some light energy is absorbed and some of it is scattered.

Activity 4: *Set up two parallel mirrors as shown and place a candle or any other object between them. What do you notice?*

KALEIDOSCOPE

A kaleidoscope (Fig. 5. 6) is an interesting toy which uses multiple reflections in plane mirrors at 60° to each other.

Three plane mirror strips of equal length and width are placed tightly against each other inside a cardboard tube. They are kept in such a way that they are inclined at 60° to each other.

At one end of the tube there is a small hole to look through. At the other end small bits of coloured glass (like the ones from a broken glass bangle) are placed between a piece of ground

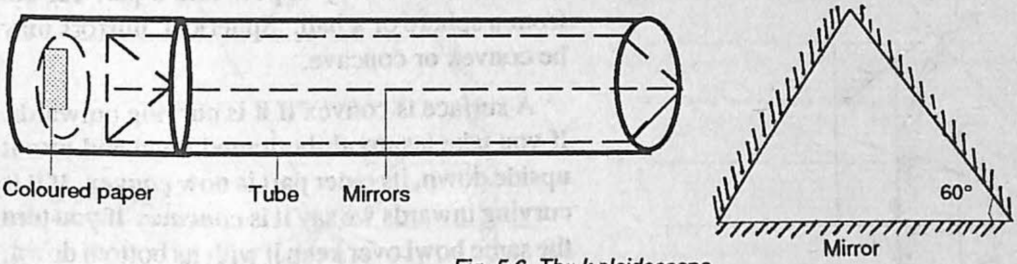
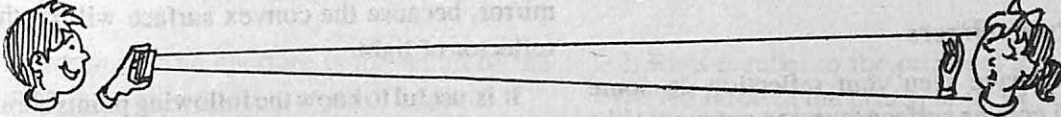


Fig. 5.6. The kaleidoscope

glass. Ground glass is slightly milky and translucent allowing some of the light to pass, but not all of it like clear glass does. When you look into the tube (holding the end with the ground glass against bright light), the glass pieces and all their images formed by multiple reflections in the three mirrors form beautiful coloured patterns.

The number of coloured patterns is almost unlimited. This is because each time the tube is shaken, the pieces of coloured glass are rearranged to give a fresh pattern. Though it is known as a toy, the kaleidoscope is sometimes used by textile designers and other craftsman for ideas for new patterns.



Activity 5: *Use a mirror to flash sunlight on another person's face. Use a mirror to throw sunlight from outside into a room or verandah. How are you able to do this?*

The mirror is obeying the laws of reflection. By holding the mirror at different angles you are reflecting the sunlight in different angles or directions. In other words, the mirror is deflecting the light.

Activity 6: *Arrange two mirrors in such a way that you can see a person behind a wall. You can arrange two mirrors to see over a wall. Do this activity in small groups.*

THE PERISCOPE

The periscope is an instrument that uses two mirrors to enable the user to see over the heads of a crowd. In a submarine, it is used to see above the surface of the sea from under water. It is used in some industries to see parts of machines which are otherwise inaccessible.

A simple periscope consists of two plane mirrors, fixed facing each other at an angle of 45° to the line joining them, i.e. to the axis of the tube. Therefore, both the angle of incidence and the angle of reflection are 45° and the ray is reflected through 90°. Parallel rays from a distant object are reflected by the mirror M_1. They travel down the tube and fall on the second mirror M_2. When reflected from this mirror, the rays are made horizontal and reach the eye of observer. Thus he is able to see a distant object. Modern periscopes use reflecting prisms instead of mirrors.

Periscopes in submarines and industries are more complicated. But, the basic principle is the same.

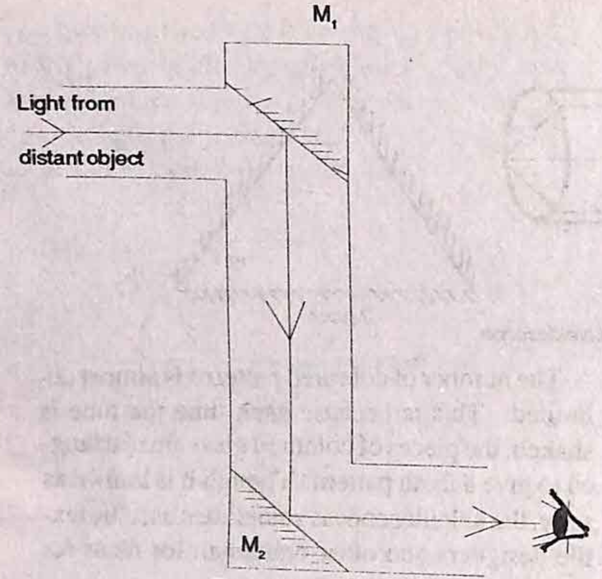


Fig. 5.7 A periscope

5.3 Curved mirrors

You may have seen your reflection on some polished convex surface (curving outwards) like a steel vessel or the curved parts of a car. The image formed is small and odd looking. On the other hand, you may also have seen your reflection in a concave (curving inwards) reflecting surface like the inside of a bright bowl. Then you would have seen your face magnified, i.e., much larger than it really is.

Mirrors that are not plane, reflect things in a different way. Ofcourse, the laws of reflection are the same. But the nature of the image is different.

Curved mirrors are called *spherical mirrors*. This is because they appear like a part cut out from a sphere or a ball. Spherical mirrors may be convex or concave.

A surface is convex if it is curving outwards. If you take a smooth-bottomed bowl and turn it upside down, its outer part is now *convex*. If it is curving inwards we say it is *concave*. If you turn the same bowl over keep it with its bottom down, its inside is now a concave surface.

A spherical mirror is made by silvering a piece of glass which would form part of shell of a hollow sphere. If the piece is silvered on the outer surface, its inner (concave) surface is used for reflecting and is called a concave mirror. If the inner surface is silvered, it is called a convex mirror, because the convex surface will be the reflector of light.

It is useful to know the following points about spherical mirrors. See Fig. 5.8 and Fig. 5.9.

i.*The centre of curvature* : The centre of curvature(C) is the centre of the sphere of which the mirror forms a part.

ii. *The pole* : The pole (P) is the geometric centre of the mirror, and is used as a reference point for measuring any distance from the mirror.

iii. *Principal axis:* The principal axis is the line which passes through the centre of curvature and the pole of the mirror.

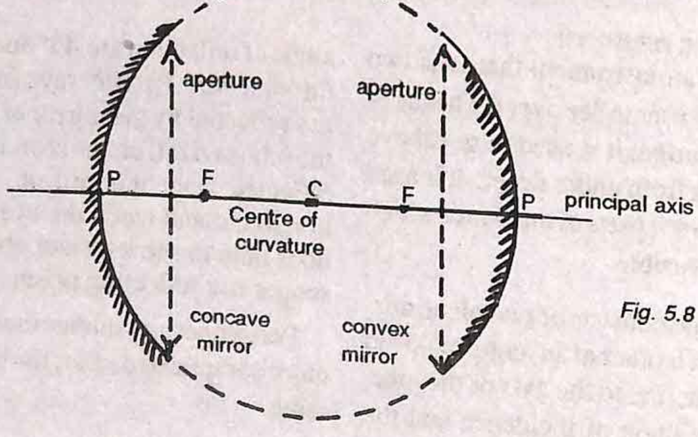
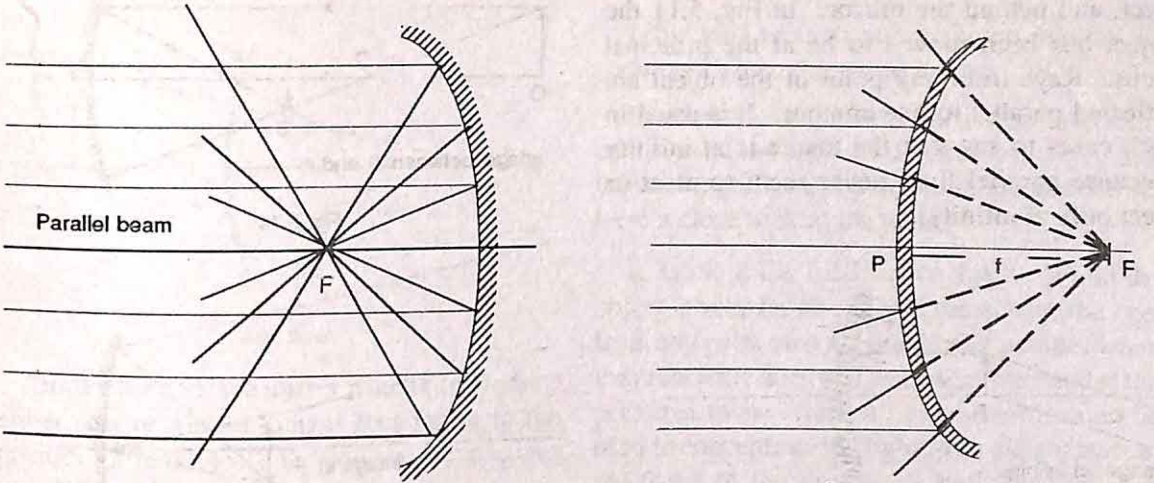


Fig. 5.8 Spherical mirrors.



Concave mirror

Convex mirror

Fig. 5.9

iv. *Aperture:* The aperture is the width of the mirror.

v. *The radius of curvature:* The radius of curvature (r) is the distance between the centre of curvature and the pole of the mirror.

vi. *Principal focus:* The principal focus (F) of a spherical mirror is that point on the principal axis on which all rays parallel to the principal axis converge (in the use of concave mirrors) or appear to diverge from (convex mirrors) after reflection from the mirror.

vii. *Focal length:* The focal length of a spherical mirror is the distance between the principal focus and the pole of the mirror.

DRAWING RAY DIAGRAMS FOR REFLECTION IN SPHERICAL MIRRORS

To show the formation of images in mirrors and lenses, we need to draw ray diagrams. Fig. 5.10 - 5.15 are diagrams showing images formed by a concave mirror for different positions of the object along the principal axis.

The following three rules shows us what happens when images are formed in spherical mirrors:

1. Rays passing through the centre of curvature are reflected back along their own paths.
2. Rays parallel to the principal axis are reflected through the principal focus.
3. Rays passing through the principal focus are reflected parallel to the principal axis.

IMAGES FORMED BY A CONCAVE MIRROR

In figure 5.10 the object is represented as a vertical arrow OA standing on the principal axis between the pole of the mirror and the principal focus. The rules of reflection in spherical mirrors are used in the construction of the ray diagrams. When the two reflected rays are drawn they seem to be diverging from a point B behind the mirror. IB is thus the virtual of IA. If the same construction is carried out for a series of other points along the object OA, a corresponding set of image points will be formed along the vertical line IB.

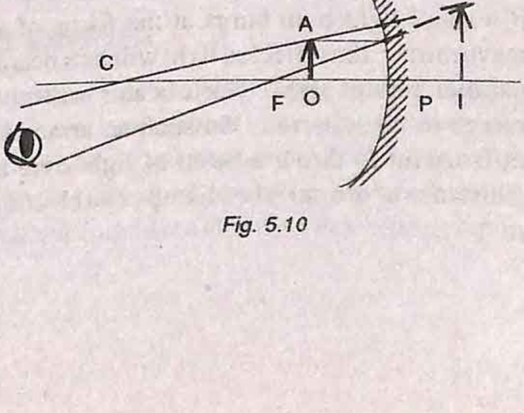


Fig. 5.10

The image formed in this case is — virtual, erect, and behind the mirror. In Fig. 5.11 the object has been moved to be at the principal focus. Rays from any point of the object are reflected parallel to one another. It is usual in such cases to say that the image is at infinity (because parallel lines never seem to meet or meet only at infinity).

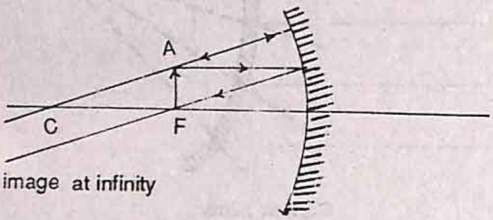


Fig. 5.11

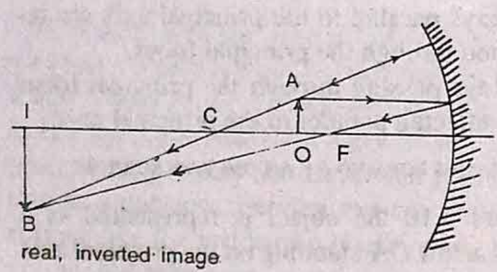


Fig. 5.12

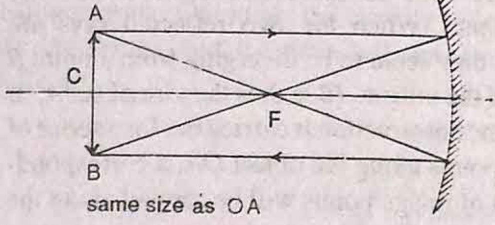


Fig. 5.13

If a small light bulb burns at the focus of a concave mirror, the reflected light will be a beam of parallel rays of light. Such beams will not converge or be scattered. So such an arrangement is useful to throw a beam of light over a long distance as in a car's headlamp or an electric torch.

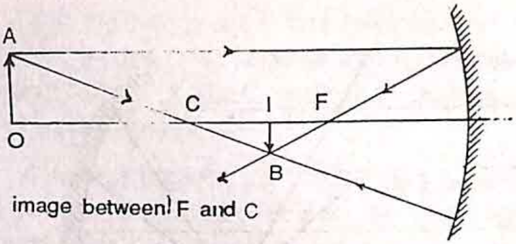


Fig. 5.14

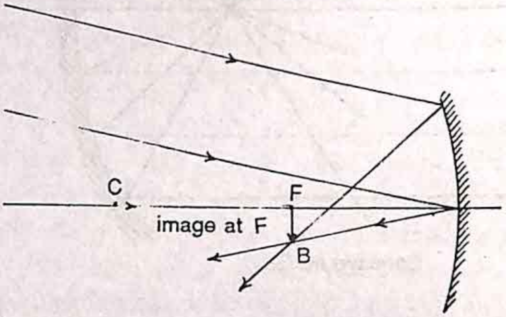


Fig. 5.15

Specially note Fig. 5.12 — 5.15 because in these cases, *real images* are formed. If a white screen is placed at the image position, the image will be formed on it.

REAL AND VIRTUAL IMAGES

It is important to distinguish between *real* and *virtual* images. A real image is formed by the *actual* intersection of rays of light. A virtual image is formed by the *apparent* intersection of rays when they have been produced backwards. The practical difference is that *a real image can be formed on a screen while a virtual image cannot be formed on a screen*. Thus you can see that, while drawing ray diagrams, it is necessary to differentiate between real rays and virtual rays by full and dotted lines respectively. This is a necessary convention. Full lines are used to indicate real rays, objects and real images. Dotted lines are used to represent virtual rays and images.

IMAGES IN CONVEX MIRRORS

Since the focal point is virtual, the focal length is also negative in a convex mirror.

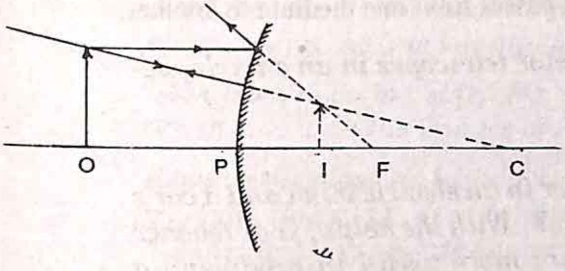


Fig. 5.16

Unlike the concave mirror which can produce either real or virtual images (according to the position of the object), the convex mirror gives virtual images only.

The virtual images formed by a convex mirror are always erect and smaller than the object.

5.4 Uses of curved mirrors

1. CONVEX MIRRORS

Convex mirrors are very convenient for use as car driving mirrors. This is because they always give an erect image and a wide field of view. Fig. 5.17 shows why a convex mirror has a wider field of view than a plane mirror.

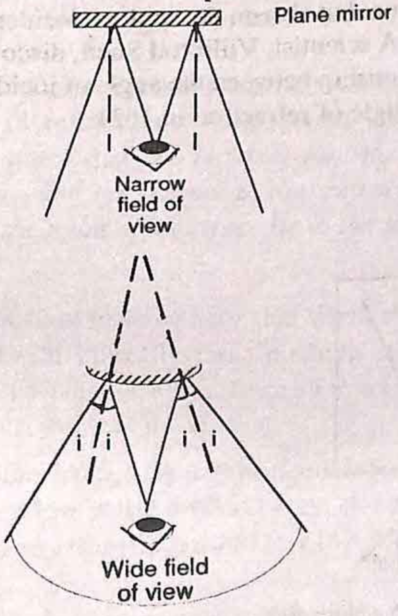


Fig. 5.17

2. CONCAVE MIRRORS

i. Shaving mirrors and make-up mirrors are concave. They give large images.

Dentists also use small concave mirrors at the end of a curved steel rod to examine teeth. The mirror magnifies the image and the dentist can have a close look at the teeth.

ii. Look at Fig.5.18 once again. When the object is very far away from the mirror, the rays from any point on it are practically parallel when they reach the mirror. The image is formed at the principal focus. Such a concave mirror can be used to concentrate the light from distant stars at the focus of the mirror. It will function as a telescope.

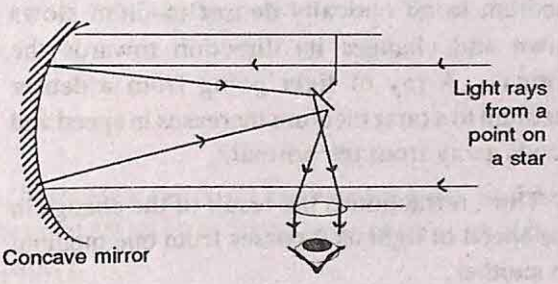


Fig. 5.18. Reflector telescope.

Such telescopes are called *reflector telescopes*. The first telescope of this type was made by Issac Newton in the 17th century. The largest reflector telescope in the world is the Hale Telescope at the Mount Palomar observatory in California (USA). (The mirror of this telescope has a diameter of 5 metres ! It is made of special glass and is coated with aluminium. It took several years to construct it. Many important discoveries about stars and other heavenly phenomena have been made using this telescope.)

5.5 Refraction

You know that a straight object, such as a drinking straw, appears bent when partly immersed in a glass of water or lemonade. This is due to light changing its direction as it passes from one medium (liquid) to another (air). The twinkling of stars and the sparkling of diamonds; rainbows and coloured skies at sunset; the blueness of the sky — all these are the result of light bending as it passes from one medium to another.

Activity 7: *Read up more about reflector telescopes in an encyclopaedia.*

Activity 8: *Observe the reflecting mirror in an electric torch and a car's head lamp. Are they concave mirrors? With the help of your teacher find out why parabolic mirrors are more useful in producing a parallel beam of light than an usual spherical concave mirror (a parabola is a curve like the path of a ball thrown into the air).*

The bending of light as it passes from one medium to another is known as *refraction.*

A ray of light going from an optically rarer medium to an optically denser medium slows down and changes its direction towards the normal. A ray of light going from a denser medium to a rarer medium increases in speed and bends away from the normal.

Thus, refraction is the result of the change in the speed of light as it passes from one medium to another.

The speed of light is maximum in a vacuum. In all other mediums its speed varies. We see that the bending of light varies greatly according to the substance through which the rays pass. We call the ability of a substance to bend light, its *index of refraction* or *refractive index. The refractive index of a substance is the ratio of the speed of light in vacuum to its speed in that substance.*

Refractive index is represented by the Greek letter 'mu' (μ).

$$\mu = \frac{\text{speed of light in vacuum}}{\text{speed of light in that medium.}}$$

LAWS OF REFRACTION

The amount by which a ray of light bends depends not only on the refractive index of the medium but also on the angle of incidence of the ray. A scientist, Villibrod Snell, discovered the relationship between the angle of incidence and the angle of refraction in 1621.

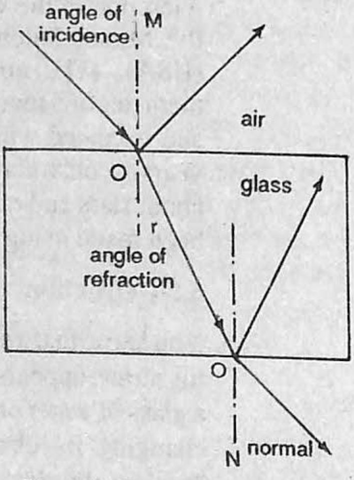


Fig. 5.19. Refraction through a glass slab

Activity 10: *Place a rectangular slab on a white sheet of paper fixed on a soft board. Trace its outline on the paper. Fix two pins A and B apart so that the line joining them is inclined at an angle to the slab.*

Look from the other side. Fix pins C and D in such a way that they are in line with the images of A and B as seen through the slab.

Remove the glass slab and join AB to meet the slab at O, and DC to meet the slab at O. Join O and O'.OO' is the refracted ray, ABO is the incident ray and the emergent ray is O'CD.

Draw the normal NM at O and measure the angle of incidence AON and the angle of refraction MOO'.

You will notice that $\angle r$ is less than $\angle i$. From the logarithmic tables, find out the values of sine r and sine i. Now, calculate the ratio of sine i to sine r. This is the refractive index of glass.

Repeat the experiment with different angles of incidence. Note your readings. You will find that sine i / sine r remains a constant. This verifies Snell's law.

Snell's law of refraction states that *the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. It is equal to the refractive index of the medium.*

$$\mu = \frac{\text{sine of the angle of incidence}}{\text{sine of the angle of refraction}}$$

Snell's law of refraction is also known as the 'first law of refraction'. The second law of refraction states that *the incident ray, the refracted ray, and the normal to the refracting surface at the point of incidence lie in the same plane.*

It is important to remember that when a ray passes from an optically rarer medium to an optically denser medium (say, from air to water), the ray bends towards the normal.

On the other hand, a ray passing from a denser medium to a less dense medium (say, water to air), bends away from the normal (see Fig. 5.19).

SNELL'S LAW

The incident ray ABO, refracted ray OO' and the normal MON all lie in the same plane (that of the paper).

EFFECTS OF REFRACTION

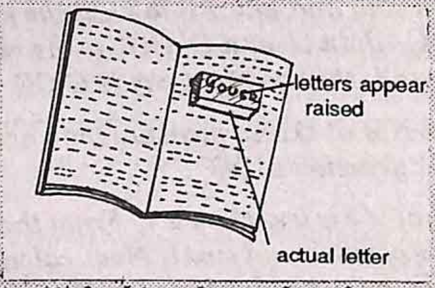
Real and apparent depth : Look into a swimming pool or a still pond. You will find that the water appears less deep than it actually is. This is because of the effect of refraction as light passes from water to air.

Any optically denser material will appear to be less deep than it actually is when it is viewed from a less dense medium.

It can be proved that the refractive index of a material, say the water in a pond, is equal to the real depth divided by the apparent or seeming depth.

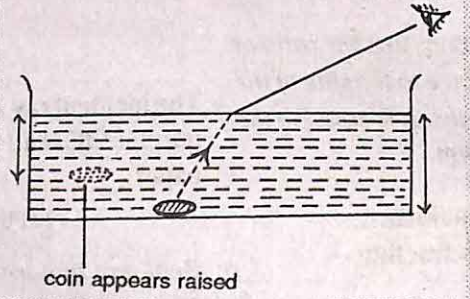
Apparent bending : When a rod is dipped at an angle in a trough of water, it will appear bent at the surface of the water. Rays of light coming inside the water refract away from the normal as they emerge from water into air. The rod therefore appears bent at the surface.

Activity 11: *Place a glass block on the following words. Read the words 'LOOKS HIGHER' through the block, like this,*



What do you see in (1) looking from above?
What do you see in (2) looking at it from an angle?

Activity 12: *Set up an apparatus as in the figure below :*



Why does this happen?

5.6 Lenses

To read this page, the lenses in your eyes have to focus the reflected light on to the screens in your eyes called the retina. *A lens is any transparent medium bounded by two surfaces of which at least one is spherical (concave or convex).*

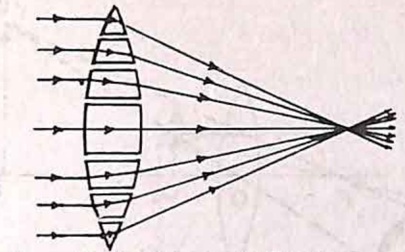
Basically, lenses are of two types: convex (converging lens) and concave (diverging lens). The two types of lenses can easily be distinguished from one another — convex lenses are thickest in the middle and concave lenses are thinnest in the middle.

Convex lenses bend light inwards (converges rays) and are sometimes called *positive*. Convex lenses can form real images.

Concave lenses bend light outwards (diverge rays) and are sometimes called *negative* lenses.

LENSES AND PRISMS

A lens can be regarded as being made up of a very large number of portions of triangular prisms. The edges of the lens act like parts of prisms which deviate light more than the other parts. Towards the centre, the lens seems to be made of parts of prisms that deviate light less (Fig. 5.20). This fact can explain many things about the properties of lenses.



lenses compared with prism

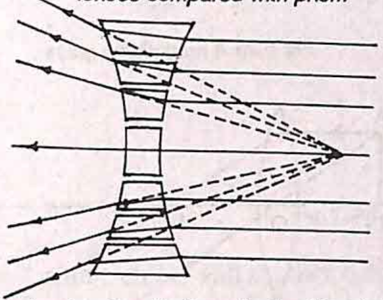


Fig. 5.20

1. The *Principal axis* of a lens is the line joining the centres of curvature of the two surfaces (Fig. 5.21).

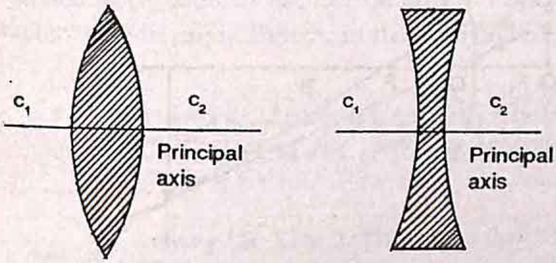
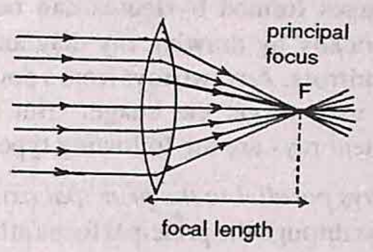


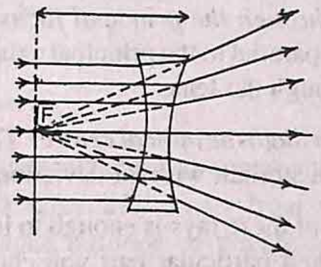
Fig. 5.21

2. If a beam of light parallel to the principal axis is incident on a convex lens, the rays after passing through the lens, converge at a point on the axis called the *principal focus*. In the case of a concave lens, the rays will spread out after passing through the lens, and appear as if diverging from a point called the focus behind the lens. So, the principal focus is real for a convex lens and virtual for a concave lens (Fig. 5.22).

The principal focus (F) of a lens is that point on which all rays parallel and close to the principal axis converge or from which they appear to diverge, after being refracted by the lens.



Convex lens



concave lens

Fig. 5.22

3. The central portion of a lens can be considered to be a small part of a parallel-sided slab. This is taken to be a point at the centre of a lens on its axis. This is known as the *optical centre* of the lens. Rays passing through this point are not deviated. So, in all diagrams, rays passing through the centre of the lens are drawn straight.

The optical centre (O) of a lens is a point on the axis at the centre of the lens through which rays of light pass without bending.

4. *The focal length (f) of a lens is the distance between the optical centre (O) and the principal focus (F).*

A lens has two principal foci ('foci' is the plural of 'focus'). This is because, as you can see, light may pass through a lens in either direction. The two foci are represented by the symbols *F* and *F'*.

Normally, the centres of curvatures of a lens is not very important, but two other points are important. These are situated at a distance twice the focal length (2*f*) from the optical centre on either side of the lens.

RAY DIAGRAMS FOR LENSES

The images formed by lenses can be located geometrically by drawing ray diagrams as we did for mirrors. Any two rays from a point source can be used to get the image. But the most convenient rays are the following types:

a. *Rays parallel to the principal axis:* These will pass through the principal focus after refraction through the lens.

b. *Rays through the principal focus:* These will emerge parallel to the principal axis after refraction through the lens.

c. *Rays through the optical centre:* These will pass through straight without deviation.

Any two of these rays is enough to locate the image. Which particular pair you choose is a matter of convenience.

Fig. 5.23 - 5.27 are a series of diagrams to show the type of image formed by a convex lens. The object is moved progressively along the principal axis, starting at a point between the lens and the focus. The object is represented by a vertical arrow *OA* standing on the principal axis. *IB* represents the image formed.

IMAGES FORMED BY A CONVEX LENS

Fig. 5.23 shows the use of a convex lens as a magnifying glass. It will be noticed that the image in this case is erect, virtual and magnified. Fig. 5.25 is of special interest, because a convex lens is used in this way in slide projectors. The lens in a slide projector will throw a magnified, real image of a slide or film on a large screen. The image is inverted and so, the slide must be put upside down in the slide projector.

Fig. 5.27 shows the way the lens of a camera produces a small, real, inverted image on a piece of photographic film.

Fig. 5.28 shows the formation of an image by a concave lens. For all positions of the object,

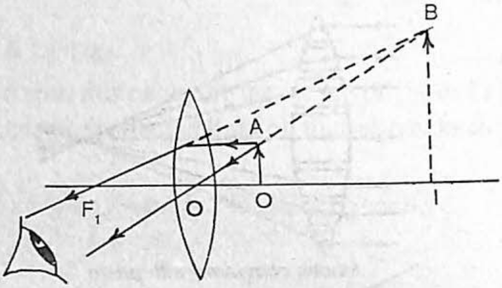


Fig 5.23 A magnifying glass

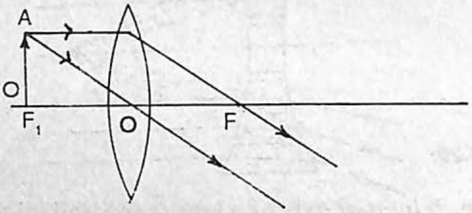


Fig 5.24 Object at focus

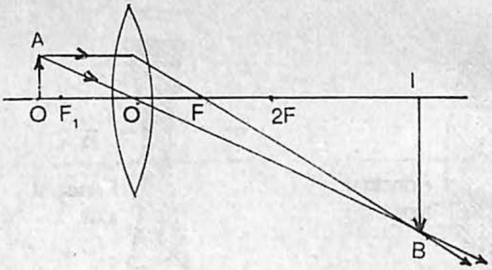


Fig 5.25 Real magnified image

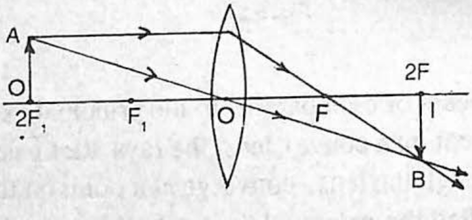


Fig 5.26 Real image same size as object

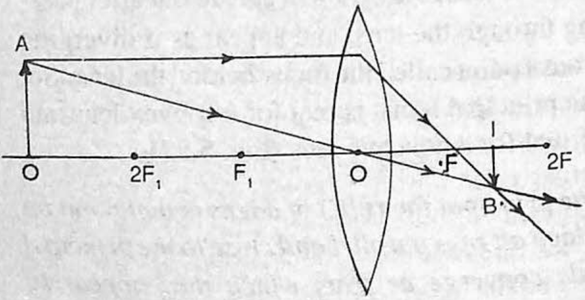


Fig 5.27 Real diminished image

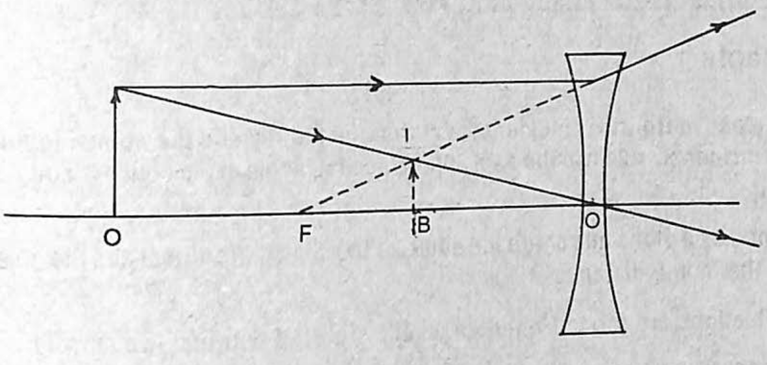


Fig. 5.28 Image in a concave lens

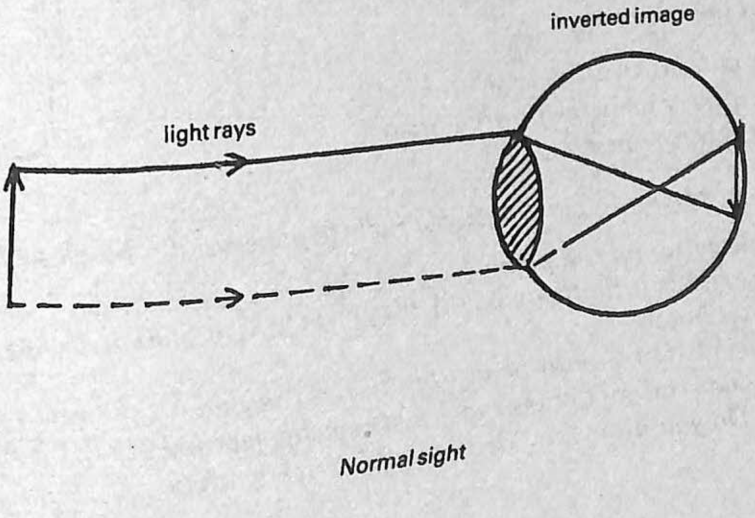
the image is virtual, erect, and smaller than the object. The image is always situated between the object and the lens.

USES OF LENSES

Lenses have been in use for centuries. Spectacles were in use in Europe in the 13th century. Lenses of many different types play an important part in our daily life. Apart from spectacles which enables millions of people to read in comfort, our lives would be very difficult if we had no cameras, projectors. microscopes or telescopes.

Activity 13: *Make a list of all the instruments which make use of lenses. Collect pictures of these and make charts.*

Activity 14: *Try to find out how the eye works as a lens.*



Normal sight

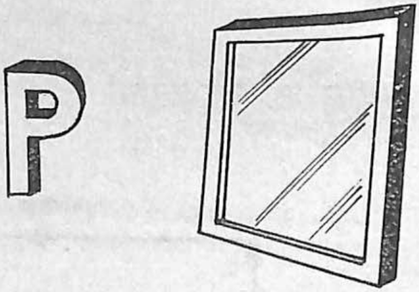
Basic concepts

1. In a plane glass mirror, the incident ray, the reflected ray and the normal to the surface at the point of incidence, all lie in the same plane and the angle of incidence is equal to the angle of reflection.
2. Images formed by a plane mirror are the same as the object, are virtual and the object distance is equal to the image distance.
3. Multiple reflections are formed when an object is placed between two mirrors.
4. The kaleidoscope and periscope make use of plane mirrors.
5. Spherical mirrors have the following positions - centre of curvature, principal axis, principal focus and pole.
6. The image formed by a spherical mirror may be real, virtual, inverted, erect, magnified or diminished according to the position of the object in front of the mirror.
7. Refraction is a change in direction of the ray when light travels from one medium to another and the ratio of the sine of the angle of incidence to the angle of refraction is a constant.
8. Spherical lenses have two centres of curvatures, two foci, an optic centre, principal axis.
9. A convex lens produces a real inverted image or a virtual erect image depending on the position of the object in front of the mirror.
10. A concave lens always produces a virtual erect image.
11. Lenses find many applications in daily life.

Some investigatory projects/activities

1. *Draw the letter P on a piece of paper and hold the paper up against a mirror. Draw the shape in the mirror.*

   A letter P is cut out in silhouette and held against the mirror as in the figure: Sketch what you see in the mirror.



2. *Magic with physics: 1. Take a piece of white paper and a black pen and a red pen.*

   Write the following on the paper keeping the lines just as it is:
   Careful, this rod is full of wonderful PHYSICS MAGIC *which makes glass invert red letters but not black*
   The word PHYSICS should be written in red ink and all the rest in black.
   Now, fix a glass rod (not glass tube) just over the words PHYSICS MAGIC. Look at the words. Do you have any idea how this trick works?

3. *Make a kaleidoscope. (Take help if necessary.) Observe the different coloured shapes which may be formed in your kaleidoscope. Sketch any interesting designs and paint them in colour.*

4. *Use a magnifying glass and observe some convenient object. Keep your eyes steady and move the lens towards and away from the object. Note the changes in the nature of the image.*

   Also, keep the lens at a fixed distance from the object and move your eyes closer or farther from the lens. What happens to the image at various positions of the eye?

   Can you explain what you observe about convex lenses?

5. *Try to devise an experiment to find out the focal length of your magnifying glass. Discuss your experiment with your teacher.*

REVISION TIME

I. *Choose the correct answer.*

1. In reflection from a plane mirror, the angle of incidence
   a. is twice the angle of reflection. b. equal to the angle of reflection. c. half the angle of reflection.

2. In a plane mirror the image is
   a. real. b. as far behind the mirror as the object is in front of it. c. inverted.

3. The image in a plane mirror is
   a. inverted. b. laterally inverted. c. larger than the object.

4. In a plane mirror, the incident ray, the reflected ray and the normal at the point of incidence are
   a. in different planes. b. at 30° to each other. c. in the same plane.

5. When two plane mirrors are inclined at an angle to each other, the number of images of an object between them formed in the mirrors
   a. is always three. b. depends on the angle they make with each other. c. depends on the ratio of the length of one mirror to the length of the other.

6. The kaleidoscope uses the principle of
   a. refraction. b. lateral inversion. c. multiple reflection and multiple images. d. change in velocity of light.

7. A spherical mirror will be
   a. convex or plane. b. converging and dividing. c. convex or concave.

8. A virtual image
   a. cannot be seen. b. can be thrown on a screen. c. is real. d. cannot be formed on a screen.

9. A driving mirror in a car is
   a. convex and has a narrow field of vision. b. is concave and has a large field of vision. c. is convex and has a large field of vision.

10. A reflecting telescope uses a mirror similar to
    a. the shaving mirror and is concave. b. the driving mirror in a car and is convex. c. a looking glass and is a plane mirror.

11. A ray of light passing from a rarer medium to a denser medium is refracted
    a. away from the normal. b. towards the normal. c. is not refracted.

12. A ray of light passing from a denser medium to a rarer medium
    a. is refracted away from the normal. b. is refracted towards the normal. c. continues in the same direction and is not bent at all.

13. The velocity of light is greatest
    a. in water. b. in air. c. in pure hydrogen. d. in vacuum.

14. A converging lens is called
    a. a periscope. b. a convex lens. c. a concave mirror. d. a prism

15. Concave lenses are
    a. more costly than convex. b. diverging lenses. c. magnifying lenses.

II *Differentiate between the following pairs :*

1. incident ray and reflected ray. 2. convex and concave mirrors. 3. real and virtual images. 4. broken lines and full lines in a ray diagram. 5. refraction and reflection. 6. real and apparent depth. 7. a spherical mirror and a spherical lens.

III *Fill in the blanks :*

1. The incident ray, the reflected ray and the normal to the surface at the point of incidence, all lie in the same ________ .
2. The angle of incidence and the angle of reflection are ________ .
3. There are two types of images ________ and ________ .
4. A ________ image is formed in a plane mirror.
5. A concave mirror ________ a beam of light.
6. A convex mirror ________ a beam of light.
7. The image in a ________ mirror is always diminished and virtual.
8. The straight line passing through the pole and the focus is called the ________ .
9. Images that cannot be formed on a screen are ________ images.
10. ________ mirrors are used as rear view mirrors in automobiles.

IV *Draw diagrams of the following :*

1. Draw diagrams to show how (a) a magnified inverted image and (b) a magnified erect image is formed by a concave mirror.
2. Show by means of ray diagrams how a converging lens may produce a magnified virtual image.
3. Draw sketches of concave and convex lenses which show why they are called diverging and converging lenses respectively.
4. Draw and label a diagram showing a ray of light being reflected from a plane mirror.

V *Write short notes on :*

1. State the laws of reflection. Are they valid for curved mirrors too?
2. Define (a) angle of incidence and (b) angle of reflection.
3. What do you understand by the term *normal* to a surface?
4. Name three most important incident rays, together with their corresponding reflected rays, which are used in constructing ray diagrams for spherical mirrors.
5. What is meant by the refraction of light?
6. What is a lens? Differentiate between converging and diverging lenses.

VI *Write detailed answers for the following :*

1. Describe an experiment to verify the laws of reflection.
2. What is the principle of multiple images in mirrors? Illustrate your answer with a diagram.
3. Write an essay on the different uses of plane and curved mirrors.
4. State the laws of refraction and describe an experiment to prove them.
5. What are lenses? Use ray diagrams to show the different positions, sizes and nature of images in convex and concave lenses, for different positions of the object.

VII *Investigatory project:*

With the help of what you have learnt about light, and your own observations try to explain the relationship between: relationship between: refraction and the blue colour of the sky.

6. Sound

Wave motion - longitudinal waves - transfers waves - reflection of sound - cause of echos and uses of echos - types of musical instruments - noise.

Every time a sound is made, there is some vibrating object somewhere. Something is moving back and forth very rapidly. Sound starts with a vibrating object.

But sound must travel in some medium. It requires something to carry the sound from the source to the hearer. A medium can be practically anything — air, water, objects, earth, etc.

If there is no medium there is no sound. If you create a vacuum, sound cannot travel through it. The reason for this is that sound travels in waves.

Imagine a row of students at the school assembly. A prankster who is last in the row gives a push to the boy before him. That boy in turn will push against the boy in front of him before he straightens up from the push of the last boy. This will continue till the boy in front of the row also stumbles forward and straightens up. You will notice that the energy of the push given by the boy in the last row, is transmitted to the very first boy without the last boy himself moving forward.

Sound waves travel very much like that. So to understand sound we must learn more about waves.

WAVE MOTION

You have seen water waves and you have also heard of radio waves, sound waves, microwaves light waves, etc. In all these, the wave motion transfers energy from one place to another. (Many forms of wave energy like radio waves and light do not need a medium to travel. But sound *does*.)

There are two kinds of waves, transverse and longitudinal. Water waves formed in a pond by dropping a stone are transverse waves. (So are radio waves.) Sound waves are longitudinal.

Transverse waves: If a stone is dropped into the middle of a still body of water like a pond, the weight of the stone creates a depression in the water. Since it is almost impossible to compress water, a ring of raised water immediately surrounds the depression created by the falling stone. The weight of this ring of raised water throws up a wider ring of water slightly away from the original centre of disturbance.

This continues and the ring of raised water moves farther and farther out from the centre.

It is important to understand that the water itself is moving only up and down because of the disturbance that is being transmitted outward in the direction of motion of the wave.

If we place a piece of cork on water that has been disturbed into ripples, you can see that the cork will rise and fall with the water it is resting on and the ripples will carry the cork in the direction of the wave.

A wave like the water wave, in which the motion of individual particles is in one direction (up- and - down in this case) and is at right angles to the direction of the movement of the wave energy , or the direction of propagation is a transverse wave.

Activity 1 : *Strike the prongs of a tuning fork against a rubber pad. Observe the prongs carefully. They appear hazy as they are vibrating very fast. Feel the vibration by bringing them lightly against your teeth. What do your feel ?*

Hold the vibrating fork over water in a wide trough. Touch the middle portion of the still water, gently with the tip of one of the prongs. What do you observe?

A transverse wave is the disturbance produced in a medium which travels at right angles to the direction of the motion of the particles of the medium.

VELOCITY, FREQUENCY AND WAVE LENGTH OF A WAVE

Fig. 6.1. represents a wave like the one produced in a still pond by a falling stone. The highest point in the wave reached by particles of the medium, because of the disturbance, is the *crest* of the wave and the lowest point is the *trough.*

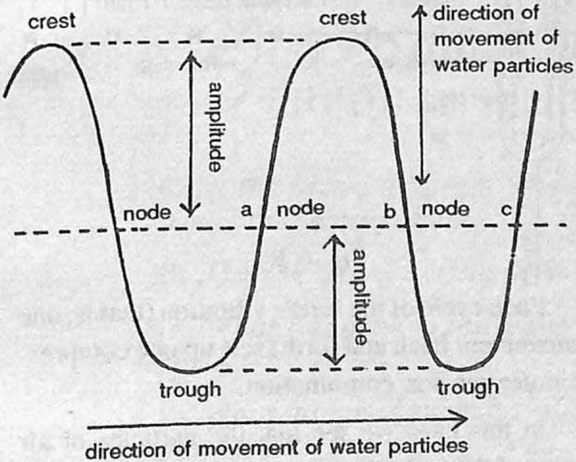

crest
crest
direction of movement of water particles
amplitude
node
a
node
b
node
c
amplitude
trough
trough
direction of movement of water particles

Fig. 6.1

Between the highest points or crests and the lowest points or troughs, there are points where the water is momentarily at the level it would be if there was no disturbance. The more force with which a stone hits the water, the higher will be the crests and lower the troughs. The distance from the original level (now represented by the node of the wave) to the highest or lowest point is the *amplitude* of the wave. (You have heard the word ' amplitude' in connection with the motion of a pendulum. Do you notice any similarity about its use in connection with waves?) In other words, the vertical distance from a node to either a crest or a trough is the amplitude of the wave.

Look at Fig. 6.1 again. Consider a node as the initial level of the water before the disturbance. We know, a water wave is a steady rise and fall which spreads outwards. Water rises from the level of a node, goes up to the level of a crest and falls down to the level of a node. Then it goes down to the level of a trough and rises to the level of a node again. This is considered as one cycle of the wave. As the wave moves outwards this cycle is repeated.

How far does the wave move outwards during 'one cycle' ? The distance from one node to another is half a cycle of the wave. (You can trace this in the figure.) So the distance the wave moves in one cycle is twice this distance. This distance is known as the *wave length.* (In Fig. 6.1 the wave length is the distance from the node *a*

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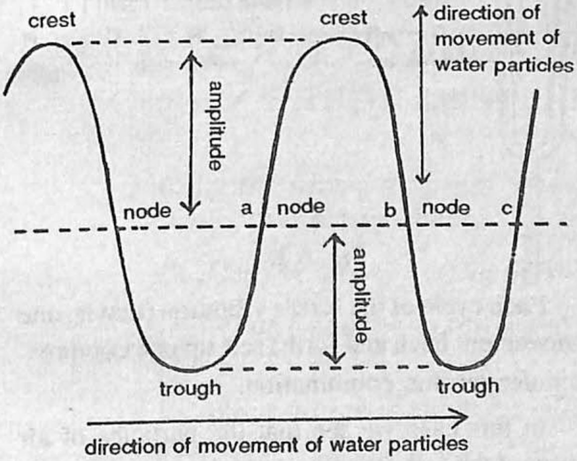
crest
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direction of movement of water particles
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How far does the wave move outwards during 'one cycle' ? The distance from one node to another is half a cycle of the wave. (You can trace this in the figure.) So the distance the wave moves in one cycle is twice this distance. This distance is known as the *wave length*. (In Fig. 6.1 the wave length is the distance from the node *a* between two successive crests or two successive troughs of the wave.

We could therefore say that, *wave length is the distance between two successive crests or troughs of a wave*.

The crest of a wave, we notice, moves outwards along the surface of the water (though, as we saw, the water itself does not move outwards). *The distance travelled by a particle on the wave per second is the wave velocity.*

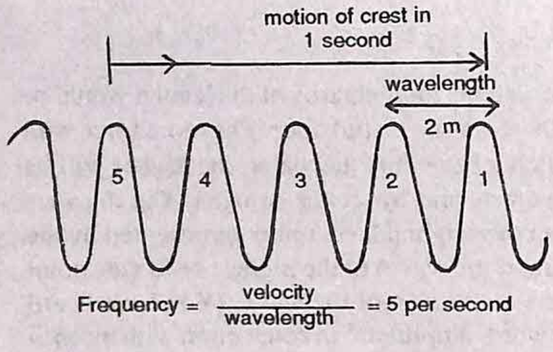


Fig. 6.2

Let us suppose that the velocity of a particular wave is 10 metres per second (see Fig. 6.2). Let its wave length (distance from crest to crest) be two metres. Now let us consider a point on the surface of the water where a particular crest is. It moves outwards. After two metres of the wave has passed, another crest will appear at this point. Since the velocity of the wave is 10 metres per second, in one second, five crests will have to pass the point to have travelled 10 metres (because the distance between two crests is 2 metres).

We know that one wave length represents one complete cycle of that wave. So, in the above case, we see that five cycles of the wave pass a given point if the velocity of the wave is 10 m/s and its wave length 2 m. This is known as the frequency of a wave.

The number of cycles of a wave passing through a point in unit time is the frequency of the wave.

We see that the frequency of a wave is equal to its velocity/wave length. The unit of frequency is hertz — Hz. One hertz is equal to one cycle/second

Wave length is represented by the Greek letter 'lambda' (λ) and the frequency by the Greek letter 'nu' (ν). Hence $\nu = v/\lambda$.

Longitudinal Waves : Sound travels as waves through the air. But the waves created by sound in air is different from water waves or transverse waves in some respects. Consider the vibration of a tuning fork. When the prong moves to the right, it compresses the air particles to the right of it. This disturbance is transmitted outwards through the air. (Similar to the push of the boy in the school assembly.)

Similarly when the prong moves to the left, the air to the right expands or rarifies and gives rise to a pulse of rarefaction.

Again, the prong moves right, then left and so on. So, a series of compression and expansion move outwards in sucession as long as the fork vibrates.

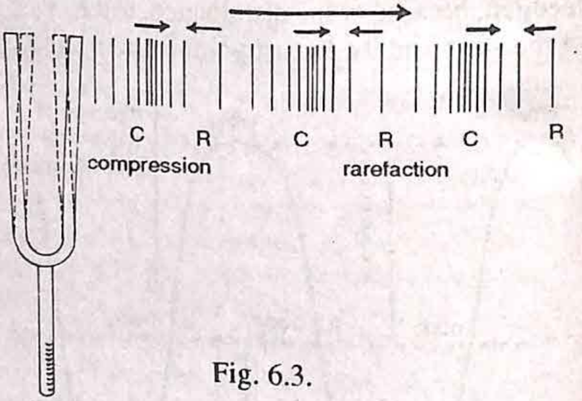


Fig. 6.3.

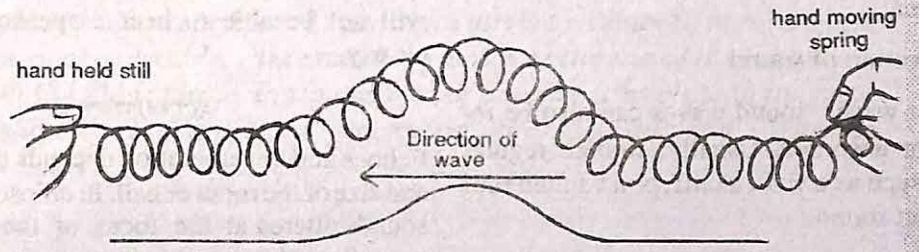
Each cycle of the fork's vibration (that is, one movement back and forth) sets up one compression/expansion combination.

In this case we see that the particles of air around the fork (the source of the disturbance in air like the stone in the water) move back and forth in the same direction as the wave.

Such a wave is a longitudinal wave. *A wave is said to be longitudinal when the particles of the medium move in the same direction in which the wave travels.*

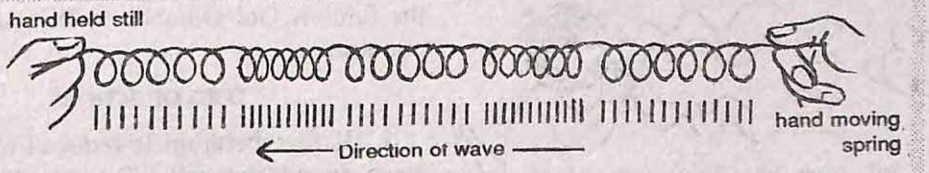
The points of compression in the sound waves corresponds to the crests in the transverse waves in water. The points of expansion correspond to the troughs in transverse waves in water. The wave length of the longitudinal wave is therefore

Activity 2: *i. Lay a stretched 'slinky spring' on the floor. Fix one end to something. Jerk the free end to the left and right at right angles to the spring. Look carefully as the energy travels down the spring. You will see that each coil moves at right angles to the direction of travel. What waves are moving through the spring ?*



Copy the above diagram in your notebook. Below it write how transverse waves travel in a slinky spring.

ii. Now, push and pull the end of the slinky spring in short jerks. You will see that each wave is moving back and forth along the length of the spring?



Copy the above diagram. Below it write how longitudinal waves travel in a slinky spring.

iii. Use the slinky spring to find out the following :

(a) What happens to the wave when it reaches the other end of the spring.

(b) What happens when a wave is sent from both ends of the spring at once ?

(c) What happens if a series of waves is sent from one end of the spring?

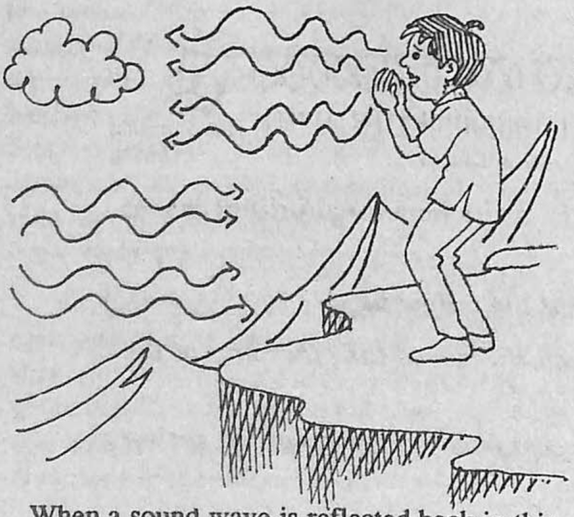
the distance between two successive points of compression or expansion.

One complete vibration of the source of the sound (the tuning fork in this case) produces one compression/expansion combination. The frequency of the wave is the number of cycles of the wave passing through a point in one second. That is the same as the number of complete vibrations (or back and forth movements) of the source of sound, which in this case is the tuning fork. So, *in the case of sound waves, the frequency is the same as the number of vibrations of the source per second.*

4.2 Reflection of sound

Like light waves, sound waves can also be reflected, or absorbed. Usually, smooth regular surfaces such as a wall, a cliff, or a vaulted roof will reflect sound.

For example, if you shout your name across a valley, after a moment, you will hear the shout once again. This is because the sound wave produced by your shout is reflected back by the hills and travels back to your ears.



When a sound wave is reflected back in this way, it is heard as an echo. *An echo is sound repeated by reflection.*

In small sized rooms the time taken for a sound wave to travel to a wall, get reflected to an opposite wall, get reflected once again to the first wall and so on, is very short. So, distinct, separate echoes will not be heard. Instead, the rapid production of echoes will merge into a dull rumble. This rumble will continue even after the original sound has died down. This persistence of sound is called *reverberation*.

You can see that reverberation is the result of many echoes produced by a sound in smaller confined areas like a room or an auditorium.

If there is reverberation in an auditorium, you will not be able to hear a speaker or music clearly.

ACCOUSTICS

Echoes and reverberation depends on the shape and size of the room or hall. In ellipsoidal rooms, sounds uttered at the focus of the ellipse will get reflected from various portions of the walls and ceilings and concentrate on the other focus at the other end of the room. In such rooms, known as 'whispering galleries', people can talk to each other in whispers even though they are at opposite ends of a large room.

There is a whispering gallery in the dome of the famous Gol Gumbaz in Bijapur. Find out about it.

USES OF ECHOES

i. If reverberation is reduced to too low a level, sounds in a hall will appear flat or 'dead'. So in auditoriums, a certain level of reverberation is needed. This is taken into consideration in constructing auditoriums.

ii Bats use echoes to find their way in the dark. A bat while flying, emits a squeak of very high frequency. (Our ears can only hear sound waves of frequencies from about 15 cycles/second to 20,000 cycles/second. The frequency of the waves produced by the bats squeak is above 20,000 hertz. Waves of such high frequencies are called *ultrasonic waves*.)

by things as small as even an insect. The bat perceives the reflected waves and can thus avoid obstacles in the dark.

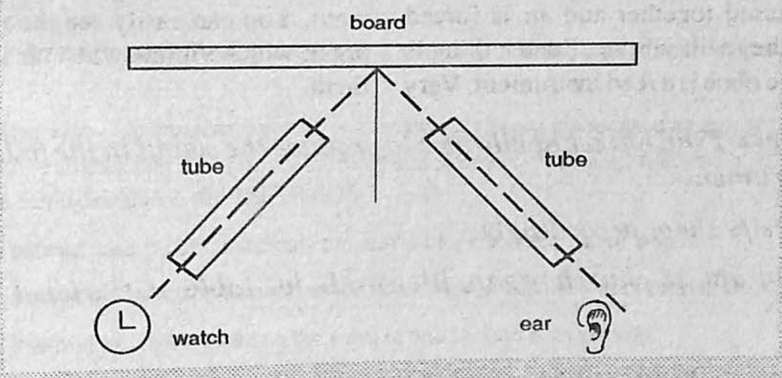
iii. *Sonar:* The principle of echoes is used in navigating ships. This is done by producing beams of ultrasonic waves underwater. These are reflected from the bottom of the sea, submarines, jutting rocks underwater and also schools of fishes. When it is used to find the depth of the sea at a point, it is known as *echo sounding.*

A beam of ultrasonic waves is sent to the depths of the sea and the total time it takes to reach the bottom and be reflected back is noted. You know that velocity x time = distance.

Since in reflection, the wave travels twice the distance to the bottom of the sea, the depth of the sea will be given by the product of the time taken and the velocity of sound in water, divided by 2.

Sonar is an abbreviation of 'sound navigation and ranging'. The echo sounding technique of sonars is used by fishing trawlers, naval ships and submarines, as well as ordinary ships.

Activity 3: *Place a cardboard tube at an angle to a smooth pane of glass kept erect on a table. Place a ticking watch at the end of the tube away from the glass plane. Place one end of another tube close to the pane as shown in the figure and place your ear at the other end. What do you hear ?*



Shift the tube so that it is at various angles to the sound. Is the sound loudest when it is at the same angle to the glass pane as the other tube? What does this tell you about the reflection of sound from a smooth surface ?

Activity 4: *Can you think of a way of finding the velocity of sound in air using echoes ? (The velocity of sound in air at normal temperature is 330 metres / second. It will be useful for you to remember this).*

6.3 Musical Instruments

Asound is considered to be musical when it is pleasing combination of sound waves of different frequencies. (The loudness of a sound also matters. Even good music played too loud may sound like noise!)

Musical sounds are produced by various musical instruments. Musical instruments can be classified according to what is vibrating in the instrument to produce sound waves. We can divide all musical instruments into four groups:

i. *String instruments*: In string instruments, sound is produced by vibrating strings. In a violin and cello, the strings are made to vibrate by drawing a bow over them. In the *guitar*, *veena*, and *sitar*, the strings are made to vibrate by plucking them either using the fingers or a plectrum.

ii.*Percussion instruments*: In percussion instruments, a membrane (like a piece of animal skin) is stretched over a frame and made to vibrate by beating with the fingers or special sticks. All kinds of drums are percussion instruments.

Activity 5: *Name some more string instruments. The piano is a string instrument. How are the strings in a piano made to vibrate ?*

iii.*Wind instruments:* In wind instruments a column of air vibrates and produces the sound. Flutes, bugles and saxophones are common wind instruments.

iv.*Reed instruments*: If two thin strips of some material are pressed together and air is forced between them, they will vibrate. Such a thing is called a reed. The oboe is a reed instrument. Very often a reed instrument also uses a column of air as in a wind instrument. Then we have a combination of reed and wind instrument. The *nadaswaram* and the *shenai* are such instruments. The mouth organ is a simple reed instrument. You can easily see the reeds in a mouth organ which vibrate when air is forced through them.

Activity 6: *Find out what vibrates to produce the sound in the following instruments.*

Classify them accordingly.

i. ghatam. ii. church organ. iii. sarod. iv. tabla v. clarionet.

Activity 7: *Find out more about a xylophone. What vibrates in a xylophone to produce the sound ? How is it made to vibrate ? How will you classify the xylophone ?*

6.4 Noise

Noise is any irregular sound, is usually unpleasant and loud.

If you visit a village or a country side, you know how quiet it is. Cities are usually very noisy. Vehicles on the road, trains, aeroplanes overhead, sirens, the noise of factories and work shops, the noise from all the radios, televisions, public speakers, processions — the list is almost endless. We get used to a lot of noise and do not notice it usually. We can include the sound of the fans, refrigerators and air conditioners in the house, in this group.

Above a certain level, sound can be painful to humans. (Try turning a portable radio to full volume and pressing the speaker to your ears !). What many of us do not know is that noise can be very bad for humans. Very loud sounds can damage our ear drums and reduce the sensitivity of our hearing (very loud fire crackers are known to have ruptured the ear drums of children). Constant noise around us also causes stress. It will make us feel irritated. Concentration is difficult with a lot of noise around you. Doctors have found that excess of noise causes the blood pressure to rise and can be very bad for our health. Noise is also very distracting and very often cause accidents in factories and on the road.

We find that in the modern world, *noise pollution* is as serious as other kinds of pollution.

Noise in the neighbourhood can be reduced a lot in many simple ways. Not playing radios, televisions and such things too loudly — play them loud enough for you to hear but not your neighbour! Not using the horns of vehicles except when essential. Keeping the silencers or mufflers of vehicles in good repair. Ofcourse, human voices need also not be raised too loud! Blaring of loud speakers in public places must be stopped. Think of more ways of reducing the noise around you.

Basic concepts

1. A wave motion is energy transmitted by a source in a medium producing a disturbance of the particles in the medium.
2. Waves are of two types - (i) transverse waves, where the particles in the medium vibrate at right angles to the direction of propagation of the wave. (ii) longitudinal waves, where the particles of the medium vibrate in the same direction in which the wave is moving.
3. The distance between two successive crests or troughs of a wave is its wave length.
4. The number of complete cycles of the wave which pass a given point in one second is its frequency.
5. The distance travelled by a given point on the wave in one second is its velocity.
6. An echo is sound repeated due to reflection.
7. Sound can be classified as musical notes and noise.

Some investigatory projects/activities

1. Have a look at the tuning dial of your radio. It is marked with the frequency (in kilohertz - KHz. 1 KHz is 1000 hertz, or 1000 cycles / second) or wave length (in metres- m) or radio stations. Find out the frequency and wave length of your favourite radio station. Can you use that to find the velocity of radio waves?

2. In Greek legends there is an interesting story about a nymph called Echo. Find out more about this story.

3. Try and find out laws and methods employed in other countries to control sound pollution. Also try and find out if any laws exist in your state and country to check noise pollution.

We must all remember that too much of noise or noise pollution can be a great danger to individual and public health. Many countries have, therefore, introduced laws and checks to control noise pollution.

4. Visit an automobile garage and try to examine an automobile silencer or muffler. Find out how it works in reducing the noise produced by automobiles.

5. Echoes multiply sounds and so increase noise pollution. From what you have learnt about echoes and sound, can you write something about the possible role of trees and foliage in reducing noise pollution?

REVISION TIME

I. Multiple choice.

i. Sound waves are
a. transverse waves. b. longitudinal waves. c. waves without energy.

ii. When a wave moves in a given direction
a. the particles of the medium move along with it. b. do not move with the wave, but vibrate i in the same direction of the wave or transverse to it. c. remain stationery.

iii. The speed of a wave
a. changes in different mediums. b. does not depend on the frequency of the wave. c. is always half the wave length.

iv. Very loud and continuous noise is
a. good for health. b. makes people happy and relaxed. c. is a danger to the public health.

II. Differentiate between the following pairs:

i. Transverse and longitudinal waves.
ii. Frequency and wave length of a wave.

III. Fill in the blanks.

i . Sound is caused by bodies ________ .

ii. Sound travels in the form of ________ .

iii. In ________ waves the particles of the medium vibrate along the direction of propagation of the wave.

iv. In ____________ waves the particles of the medium vibrate perpendicular to the direction of propagation of the wave.

v. The velocity of sound waves in air at normal temperature is about ________ m/s.

vi. Longitudinal waves travel as ________ and ________ .

vii.Transverse waves travel as ________ and ________ .

IV. Write short notes on:

i. Define frequency and wave length.
ii. What is the relationship between the velocity, frequency and wave length of a wave?
iii. What are echoes? Describe how a bat uses echoes to find its way in the dark.
iv. What is an echo sounder in a ship called? What are its uses?
v. Write a short note on noise pollution.

V. Answer the following in detail.

i. Write a short essay on transverse and longitudinal waves.
ii. Describe an experiment to show the reflection of light. What are the advantages and disadvantages of echoes.

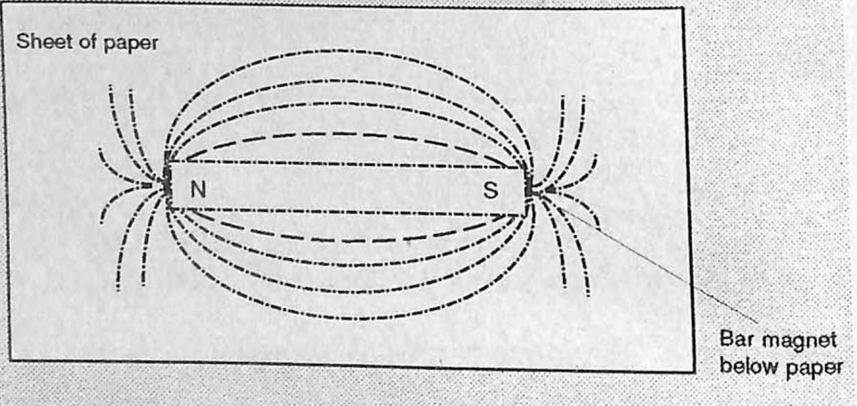
7.Magnetism

Magnetism - magnetic field - molecular theory of magnetism - magnetic behaviour of the earth

7.1 Magnetic field

You have already learnt that one magnet is able to move another from a distance of several centimetres. It is, therefore, clear that it must be producing an effect in the volume of space around it. The space surrounding a magnet in which magnetic force is exerted is called magnetic field.

Activity 1: *Place a bar magnet beneath a large sheet of paper. Sprinkle a light dust of iron filings over the paper. Now, gently tap the paper once or twice. You will find that the filings under the influence of the force of the magnet's field, become arranged in a pattern of lines.*



These lines represent the lines of force exerted by the magnet's field. They show the direction of the magnetic force at any point in the magnetic field. They are known as magnetic lines of force. *A region around a magnet or a coil of wire (with current running through it) where there is a magnetic effect is called a magnetic field.* We can represent a magnetic field by drawing lines.

The field lines show the path the cork would take in the example below.

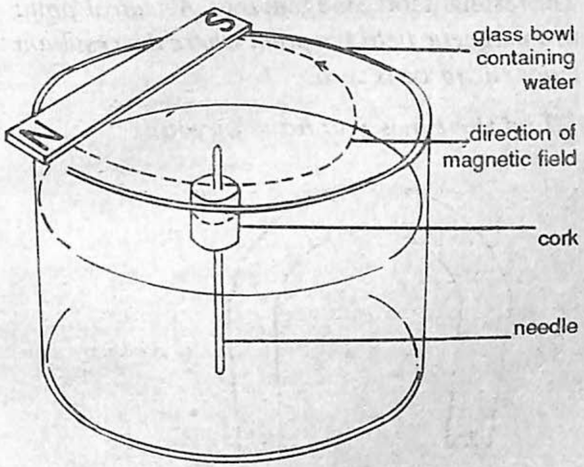


Fig. 7.1 Direction of magnetic field

PLOTTING MAGNETIC FIELDS

As we saw, the region round a magnet is called magnetic field because a magnetic force can be detected there. The lines in the field showing the direction of the magnetic force are called *field lines* or *lines of force* of a magnetic field.

A compass-needle is more sensitive to magnetic force than iron filings because it can turn more easily. To map out or trace a field round a magnet, the compass is placed near one end of the magnet (preferably, the north pole end, N). After the needle has settled down, the positions of the two ends *A*, *B*, are marked with a pencil (Fig. 7.2). The compass is now moved so that its south pole is at *B*. The new position *C* of its north pole is marked.

Thus by moving the compass along, a series of dots is obtained on the paper and a smooth curve is drawn through them. This gives one line of force. Other lines are drawn in a similar way, beginning near a pole of the magnet each time.

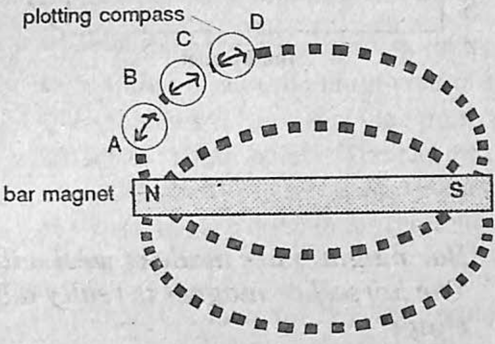
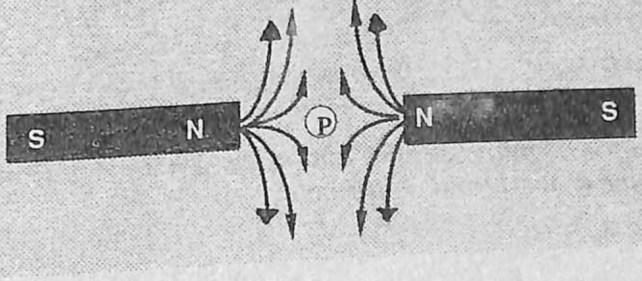


Fig. 7.2 Plotting a magnetic field

By convention, arrows are placed on all lines of force to show the direction in which the north pole of a compass needle would point on that line.

PLOTTING THE FIELD BETWEEN THE
N POLES OF TWO MAGNETS

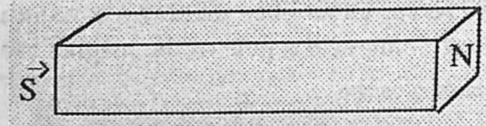
Activity 2: *Use the same method above to plot the field lines formed by the north pole of two magnets facing each other. When the field between the same poles of two magnets (in this case, the N poles) are plotted, you will find that the lines of force turn away from a certain point P.*



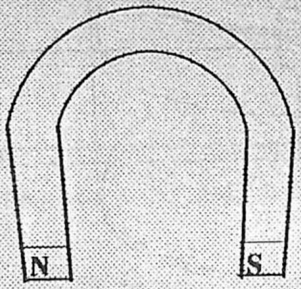
We observe that, there is no magnetic force at P. Therefore, P is called a *neutral point* in the field.

We can explain the neutral point in this way: Imagine a north pole at P. It will be repelled by one north pole with a force exactly equal and opposite to that exerted by the other north pole. The two forces cancel each other. The resultant force is zero. Imagine a south pole at point P. It will be attracted by one N-pole with a force equal and opposite to that exerted by the other N-pole. The resultant force is again zero. *A neutral point in a magnetic field is a point where the resultant magnetic force is zero.*

Activity 3: *Look at the magnets below. List the types you have in your laboratory.*

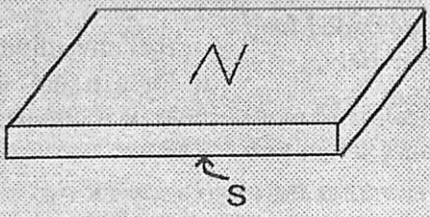


Bar Magnet



Horseshoe magnet

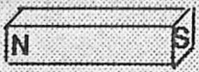
Bar magnets are made of steel with a magnetic pole at each end. The horseshoe magnet is really a bar magnet bent into a horseshoe shape.



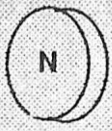
Slab Magnet

A slab magnet has a magnetic pole on each face. It is made of ceramic material and breaks easily. It is also called a magnadur magnet.

Round Magnet



Ticonal magnet



Bicycle dynamo magnet

Magnets come in many shapes and sizes. There is only one rule — they all have a north and south pole.

7.2 Molecular or domain theory of magnetism

Scientists have suggested theories (a theory is an explanation about some fact) about magnetism from the seventeenth century itself. You know that a steel bar can be magnetised by stroking it with a magnet. At first, people thought that some magnetism left the magnet and entered the steel bar when this happened. But, when the magnet was tested, its magnetic power was not found to be reduced though it was used to magnetise the steel bar. In fact, the same magnet could be used to magnetise hundreds of steel bars without losing any magnetism.

A scientist, called Weber, around the year 1840, suggested that the molecules of a piece of iron or steel, whether magnetised or not, were themselves tiny magnets. Sir James Ewing expanded Weber's ideas, and the theory came to be known as the *molecular theory of magnetism.*

Today, we explain the fact of magnetism using the basic theory put forward by Weber and Ewing. The explanation is known as the molecular theory of magnetism or, more accurately, the *domain theory of magnetism.*

THE DOMAIN THEORY OF MAGNETISM

There are four basic magnetic materials, *iron, steel, nickel, and cobalt,* plus alloys containing these metals. According to the molecular theory, or the domain theory of magnetism, these metals have groups of molecules, known as *domains,* which act as if they themselves are small magnets.

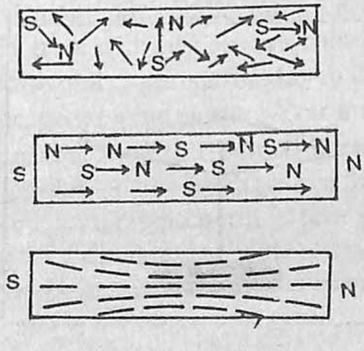


Fig. 7.3 Domain theory

These domains are always magnetised, even when the material itself is unmagnetised. The molecules in each domain together have a resultant magnetism. We can represent a domain by drawing an arrow with one end as the north pole and the other as the south pole. Fig. 7.3 shows how the domains may be arranged in an unmagnetised material. The magnetism in the domains form *closed chains* with their neighbours. (The figure is to give you a rough idea of closed chains in an unmagnetised material.) Since the effect of the neighbouring S and N poles *cancel* each other, there is no magnetic effect outside the chain. So the material appears unmagnetised.

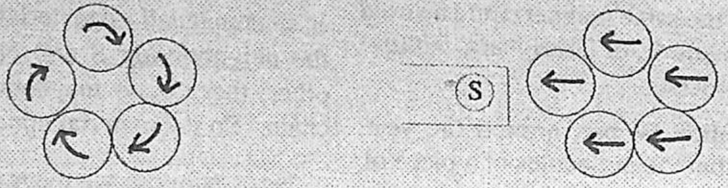
Now, suppose we magnetise such a material by stroking it with the north pole of a magnet. The magnet will now repel the north poles and attract the south poles. The closed chains are thus disturbed. As the stroking continues, the magnets in each domain turns round and points in one direction.

When the material is fully magnetised, the north poles of all the domains will point in one direction and the south poles in the other direction. The chains of domains are now open-ended (there are no opposite poles to cancel out the effect of the poles at the ends of the material.) Therefore, one end will behave like a south pole and the other end like a north pole. So, the material behaves like a magnet.

In magnets, then, the domains form 'open' chains. Fig. 7.3 b, shows the open chains in an ideal magnet. But actually, these chains are as shown in Fig. 7.3 c. The chains of domains curve away from each other at the ends of the material, since the poles at the end repel each other. That is why, in practice, iron filings are attracted round the sides of the magnet as well as at the ends.

(You must remember, it is only the magnetism in a domain which changes direction. The molecules of a domain themselves do not move.)

Activity 4: *Arrange five compass-needles near each other forming a closed chain, as shown in the figure . When the south pole S of a magnet is brought near this arrangement, the magnets swing around and point towards S, forming an open chain. When S is taken away, the magnets fall back to their closed chain position.*

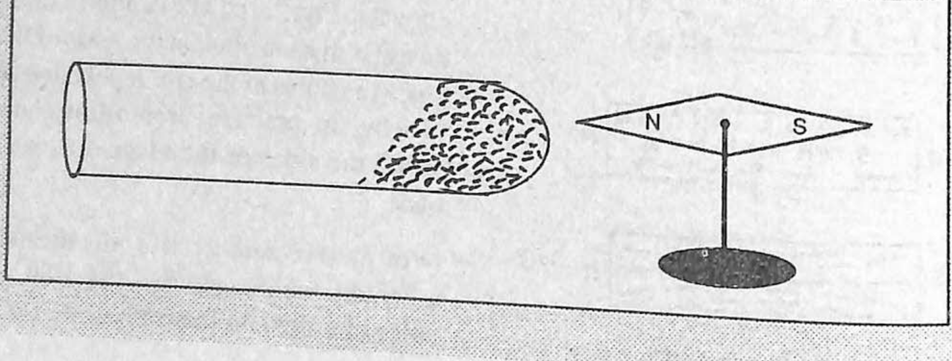


i. This experiment shows that closed chains of small magnetic units become open chains when a magnetic force is brought near it. (Try thinking of the compass-needles in the above experiments as domains in a bar of soft iron. It may help you to understand why some materials make temporary magnets and others permanent magnets.)

ii. When a steel magnetic needle is broken in two parts, each part becomes a magnet (as shown by testing it with a magnetic needle). When the two parts are broken, each new part also becomes a

Activity 5: *Bring the closed end of a testtube filled with iron filings near either pole of a magnetic needle. You will see that the needle is attracted in each case. What does this prove?*

Now stroke the test tube repeatedly with one pole of a powerful magnet and again test its end. What do you see? What does this prove? Vigorously shake the test tube and test the end again. What do you notice? What does this prove?



magnet. This experiment shows that, if you go on breaking a magnet into smaller pieces, no matter how tiny they may be, each part is a magnet.

iii. You might have realised that when the unmagnetised iron filings were brought near the compass needle, both its poles were attracted towards the filings because they were not magnetised at that time. When it was tested the second time one end was attracted towards it and the other end was repelled because the iron filings at one end of the test tube had become magnetised. Therefore, the iron particles are lined up in an open chain. When the iron filings were shaken up they lost their magnetism and became closed chains again.

iv. Finally there is another piece of evidence to support the molecular or domain theory of magnetism. Experiments show that if a piece of steel is stroked repeatedly with one pole of a strong magnet, the magnetism produced does not increase indefinitely. At some point the steel becomes magnetically saturated.

This can be explained by the molecular theory. What happens is, the magnetism in the steel increases till all the closed chains become open. Then it becomes magnetised to the maximum. After that its magnetism does not increase however much you stroke it with a magnet.

7.3 Magnetic behaviour of the earth

A pivoted magnetic needle (or a bar magnet suspended from a string) always comes to rest with its north pole pointing roughly in the direction of the geographic north. You must have seen compasses used to find the direction. In such compasses too, the north pole of the needle points to the geographic north. Have you ever wondered why a magnetic needle always points approximately in the north-south direction?

Magnets are known to have existed from very early times. More than two thousand years ago, for example, the Chinese went on long journeys with the aid of a special piece of rock or mineral suspended in the stern of the ship. This mineral was a natural magnet. It was called *loadstone* or 'leading stone' by early navigators because it always came to rest pointing roughly in a north-south direction when suspended. Since it gave an approximate north-south direction, the magnet was used as a compass or direction finder in ships all over the world. It still serves the same purpose in many ships today.

Since a freely suspended or pivoted magnetic needle always comes to rest pointing approximately north-south, it follows that the earth acts like a magnet.

Since the north pole of the magnetic needle points roughly to the geographic north of the earth, we can say that the south pole of the earth's magnetic field lies close to the geographic north. Similarly, the pole near the geographic south pole must be of north magnetic polarity.

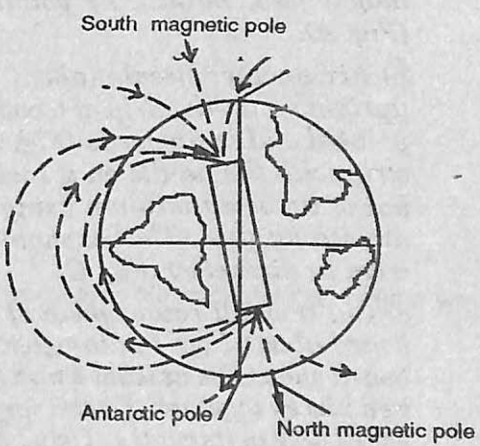


Fig. 7.4 Representation of earth's magnetic field

So, we can imagine the presence of a gigantic natural magnet inside the earth. This is represented in Fig. 7.4. This giant bar magnet at the centre of the earth, would have a length of about 4000 km. Its south pole would be inclined at a small angle to the earths axis. The north magnetic pole would be about 2000 km west of the geographic north pole.

All that we have said above about the properties of the earth's magnetic field is true, except that there is no giant magnet inside the earth !

Actually, all that we can definitely say is that there is a magnetic field around the earth. The field behaves in such a way that there are magnetic poles close to the earth's geographic pole. Close to the geographic north pole the earth has a magnetic pole showing south polarity (though we call it the north pole). And it shows the opposite magnetic polarity close to the south geographic pole.

The origin of the earth's magnetism is at present not very clear to scientists. It remains one of the unsolved mysteries of science. Today, scientists believe that the magnetic effects of the earth is produced by very complex electric currents flowing in the interior of the earth. (So, the origin of the earth's magnetism is one fact you can investigate if you become a physicist).

Activity 6: *Make a model compass using a steel sewing needle about 5 cm long. You can follow these steps:*

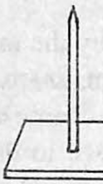
a) Magnetise the needle so that its pointed end is a north pole. Do this by stroking the needle repeatedly with the south pole of a strong bar magnet. Each stroke should begin at the thick end of the needle and end at the pointed end. After the needle is magnetised, paint the pointed end red (Fig. A).

b) Fix another needle (about 3 cm long) upright on a thin strip of wood so that the pointed end is upwards (Fig. B). Fix the strip with the needle on it inside a round box of tin or aluminium using 'Fevicol' or any strong glue. (The box should be at least 6 cm in diameter) (Fig. C).

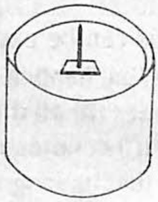
c) Cut a small round piece of thick cardboard about 1 cm in diameter. (The cardboard should be at least 2 mm thick. Stick two pieces together if necessary.) Make a small hole in its centre. Using fevicol, stick the magnetised needle to the round piece of cardboard, so that the mid-point of the needle falls over the hole (Fig. D).

d) Place the round piece of cardboard on the needle fixed to the round box . If the hole in the round piece of cardboard is too tight, make it larger till it and the magnetised needle above it turn freely on the tip of the upright needle (Fig. E).

A



B



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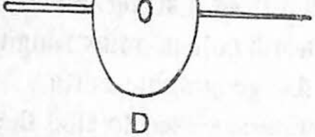

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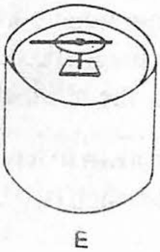


E

Use your compass to find the directions of things around you. Is your house north, east, west or south of your school?

Try other ways of making compasses.

(The simplest compass you can make is to suspend a magnetised needle from a thread. It will come to rest with its north pole pointing to the north.)

Basic concepts

1. The region around a magnet in which magnetic force is exerted is called magnetic field.
2. The direction of a magnetic field is the direction in which the north pole of a compass needle points when placed in the field.
3. According to the molecular theory of magnetism, magnetic materials are considered to have tiny regions inside them called domains.
4. The domains in unmagnetised materials are arranged in a closed chain. In magnets, the domains are arranged in an open chain.
5. The earth behaves like a magnet whose north pole points to the geographic south pole and whose magnetic south pole points to the geographic north pole.

REVISION TIME

1. Choose the correct answer

1. The lines of force in a bar magnet run
a. from the north pole to the south pole. b. from the south pole to the north pole. c. neither way.

2. The molecular theory of magnetism is also known as
a. atomic theory. b. the domain theory of magnetism. c. induction .

3. When a material is magnetised, its magnetic domains
a. form a closed chain pattern. b. form an open chain pattern. c. move from one end of the material to the other.

4. A magnetic domain in a material is
a. a group of molecules showing magnetism. b. the smallest particle of the material that can take part in a chemical reaction. c. one atom of the material.

5. The earth's magnetic effect is produced by
a. a giant natural magnet inside the earth. b. tides and the moon's attraction. c. very complex electric currents flowing in the interior of the earth. d. the gravitational pull of the sun.

2. *Differentiate between the following pairs :*

   1. The north pole of a magnet and the magnetic north pole of the earth.
   2. Magnetic north and geographic north of the earth.

3. *Fill in the blanks*

   1. The region or space around a magnet in which its magnetic effect can be felt is called a ________.
   2. A ________ ________ is a line in a magnetic field along which a north pole moves freely, and its direction is from magnetic north to south.
   3. The compass needle points to the north because the earth behaves like a ________ .

4. *Sketch the pattern of the magnetic lines of force around each of the following:*

   1. Around a bar magnet. 2. Between two south poles. 3. Between one south and one north pole.

5. *Write detailed answers for the following:*

   1. Define the term magnetic field. How can you trace the lines of force around a bar magnet? Illustrate your answer using suitable diagrams.
   2. Describe the molecular theory of magnetism using necessary diagrams. How will you use the theory to explain why a steel bar cannot be magnetised beyond a saturation stage?
   3. Describe the magnetic properties of the earth. How is the earth's magnetic field used to find directions?

8. Static Electricity

8.1 Types of charges

More than 2000 years ago (about 300 BC), the Greeks knew that particles of chaff were attracted to the amber necklaces which workers wore in the fields. They called this phenomenon 'electricity', from the Greek word for amber.

Later, many substances were found to possess the power of attracting light particles, after they were rubbed with certain materials. These substances were said to be electrified or *charged*.

Activity 1: *Rub a plastic pen, ruler or a rubber balloon vigorously on your sleeve. Then bring them close to small pieces of paper. The pieces of paper will fly up and cling to the balloon, pen or ruler.*

So, stationary, or electrostatic charges were known from about 300 BC. But, electric charges which flow through a medium (that is, an *electric current*), like the electric current from a battery, was discovered only in the nineteenth century.

POSITIVE AND NEGATIVE CHARGES

Charge a small ebonite rod by rubbing it with fur. Suspend it by a thread from a stand. Now this ebonite rod can be used to test charges on susbtances.

When another ebonite rod, charged by rubbing with fur, is brought near it, the suspended ebonite rod is repelled (Fig. 8.1a). When a glass rod, charged by rubbing with silk, is now brought near it, the ebonite rod is attracted to it (Fig. 8.1b).

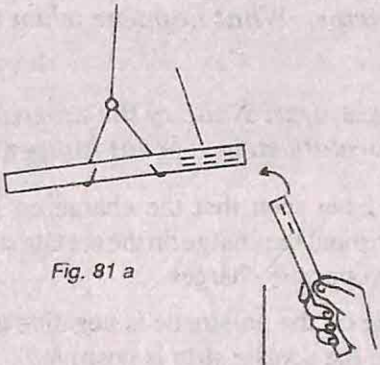


Fig. 81 a

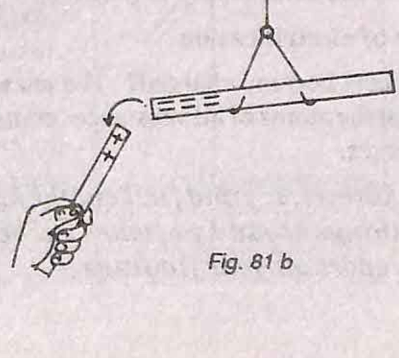


Fig. 81 b

From these effects, we can conclude that the charge on ebonite is different from the charge on glass.

Scientists distinguish between the two charges. Benjamin Franklin (a famous American scientist, who lived during the 18th century), called the charge on an ebonite rod rubbed with fur, *negative*. He termed the charge on glass rod rubbed with silk, *positive*. Experiments show that *most substances when rubbed, acquire either a negative or a positive charge*.

FUNDAMENTAL LAW OF ELECTRIC CHARGES

From the experiment described above, we see that two negative electric charges repel each other. A positive electric charge attracts a negative charge.

These facts are summarised by the rule:*Like (similar) charges repel and unlike (opposite) charges attract*. This is a fundamental law similar to the fundamental law of magnetism, which says that like poles repel and unlike poles attract.

The effects of static electric charges are all around us. What do you see when you take off nylon clothes and shake them in a dark room? What do you hear when you play an old gramaphone record without cleaning it? A lightning flash is caused by the build-up of electric charges on a thunder cloud.

Electrostatics is the study of electric charges that build up on objects.

Activity 2a: *Rub a polythene (white plastic) strip with a dry duster. Hang it from a piece of string. Rub another polythene strip with the duster. Bring it close to the first strip, without touching it. What happens?*

Activity 2b: *Repeat the experiment using two acetate (clear plastic) strips. What happens when they are brought near each other?*

Activity 2c: *Now try the experiment using one polythene strip and one acetate strip . What happens this time?*

You will have seen that the charge on the polythene strip and the charge on the acetate strip are unlike or opposite charges.

The charge on the polythene is negative and the charge on the acetate strip is positive.

8.2 Theory of electrification

How do objects become charged? The answer simply is that the atoms of all substances contain electric charges.

Actually, the atoms of all substances contain 'particles' with positive electric charge (*protons*) and other 'particles' with negative electric charge (*electrons*).

An atom is so small that we cannot see it with the best optical microscope. Protons, which are particles carrying positive charges in an atom are concentrated in a small central part of the atom called its *nucleus*.

Activity 3: *Try and find out the kind of charge acquired by various other things around you when rubbed with a dry cloth duster. Write a short report on your findings.*

Electrons, which carry negative charges, are very light and move around the nucleus.

When a substance is not charged, it is said to be *neutral*, i.e., it contains equal numbers of electrons and protons. The negative charge on the electrons cancels out the positive charge of the protons. It is not clearly understood as yet how plastics and such objects become charged.

However, scientists think that when, for example, a glass rod is rubbed with a piece of silk, the friction causes electrons to be transferred from the glass to the silk. The silk now has more electrons than protons, and the glass has less electrons than protons. The glass is left, therefore, with an overall positive charge. The piece of silk is left with a negative charge because it has received some electrons.

When an ebonite rod is rubbed with a piece of fur, the opposite happens. The fur loses some electrons and becomes positive. Due to friction during rubbing some electrons are transferred from the fur to the ebonite rod and the ebonite rod becomes charged negatively. You should note two things carefully:

i. Rubbing causes electrons to be transferred from one substance to another. Rubbing does not create an electric charge. It is the transfer of electrons which causes bodies to become charged.
ii. In all cases of bodies becoming charged, it is only the negative charges that move. The positive charges remain fixed.

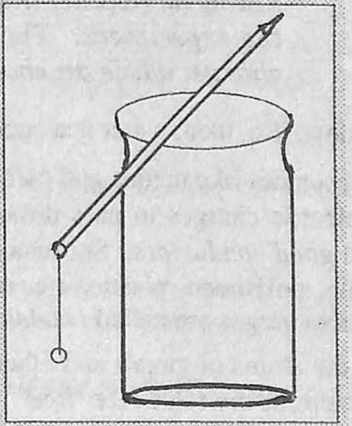
ELECTROSCOPE

An electroscope is used to detect and measure the quantity of charge in a body. It consists of a metallic rod with a metallic head at the upper end. Two thin metallic leaves which fly apart when a charged body is brought near it, are attached to the lower end. The lower end is enclosed in a metal jar.

MAGNETISM AND ELECTROSTATICS

We learnt in the last chapter that the behaviour of charged strips should be distinguished from the behaviour of magnets.

Activity 4 : *Roll up about* $6\ cm^2$ *of metal foil from a cigarette or chewing-gum packet into a ball of about 6 mm diameter. Use an adhesive to attach it to a piece of silk or nylon thread about 8 cm long. Secure the free end to a ball pen or other insulator and rest the pen across the mouth of a jam jar so that the ball hangs clear of the side (see diagram). Bring any charged body near the ball. It should first be attracted and then jump away. Now rub another plastic pen on a celluloid set-square or protractor. Hold the pen near the ball and let it take a charge. Now bring the protractor near the charged ball. What does this tell you about the two kinds of charge produced by rubbing? Use your electroscope to test the charge of various bodies.*



A magnet has different poles at each end. A charged body gains the *same kind of charge all along its length*.

So, although charges and magnet poles have similar rules of attraction and repulsion, they really have nothing to do with each other. For example, a +ve or –ve charge has no effect on a magnet.

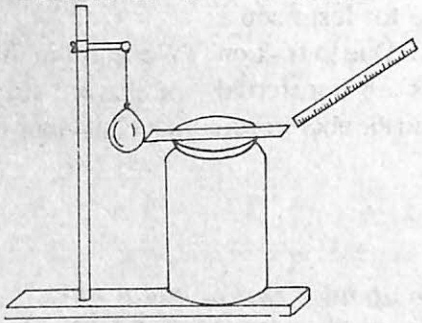
8.3 Conductors and insulators

It was discovered by the scientist Gray in 1729 that charged conductors lose their charge when suspended by a metal wire, but retain it when suspended by a silk thread. He came to the conclusion that the metal wire conducts electric charge but silk does not. He also found that the charge was lost when the silk thread was covered with dew. So, then, water is a conductor.

Activity 5 a: *Coat a small balloon with powdered graphite paste to make it conducting. Suspend it by a silk thread from a stand. Place a metal rod on a beaker and keep it near the balloon in such a way that one end of the rod just touches the suspended balloon.*

Touch the free end of the metal rod with a charged polythene strip as shown in the figure. What happens?

The balloon flies off showing that the metal rod and the graphite paste-coated balloon have acquired similar charges, which have flowed from the charged strip through the metal rod to the balloon.



Activity 5b: *Replace the metal rod with an ebonite or glass rod. Repeat the experiment. You will see that a metal rod conducts electrical charge, while an ebonite or a glass rod does not.*

Substances like metals and carbon which allow electric charges to pass through them are called *good conductors*. Substances like glass, ebonite, polythene, plastic, etc. which do not conduct charges are called *insulators*.

In the atoms of metals and other conductors, the electrons are relatively 'free'. So, they can move from one part of the substance to another. That is why they are able to conduct charges.

In the atoms of insulators, the electrons are firmly 'bound' to the nucleus. So they are unable to move from one part to another and so cannot conduct charges.

The human body is a good conductor. If you touch a live wire (do not try it) some of the electricity flowing through it will pass through our body and to the ground; and you will get an electric shock.

Activity 6 : *You may have charged a plastic rod by holding it in your hand and rubbing it against your sleeve. Plastic is an insulator. Why can't the rod be held this way if you are charging a conductor? What would happen to the electric charge if you do so?*

Two balloons are rubbed on a piece of wool and hang near each other from pieces of cotton thread. Can you say what will happen to the balloons. Why does this happen? Try the experiment.

Basic concepts

1. Negative charge is formed on an ebonite rod rubbed with fur; positive charge is formed on a glass rod rubbed with silk.
2. Electrons carry negative charges, and protons carry positive charges.
3. When two bodies are rubbed, electrons are transferred from one to the other. The body which gains electrons has negative charge and the body which loses electrons has a net positive charge.
4. The charge acquired by a body depends on the material with which it is rubbed.
5. Like charges repel; unlike charges attract.
6. Conductors allow electric charges to pass through them easily. Insulators do not carry charges through them.

Some investigatory projects/activities

1. *When a colour TV set is switched off, you sometimes hear a crackling sound from the screen. What is causing this?*
2. *When you pull out a gramaphone record from its cover it gains a static charge. How will you use a positively charged electroscope to find out whether the record is +vely or –vely charged?*
3. *Plasticine films often used to wrap food usually sticks to itself and the food containers. Why?*

REVISION TIME

I. *Choose the correct answer.*

1. A positively charged glass rod
   a. is a north magnetic pole. b. has more protons than electrons. c. attracts the south pole of a magnet.
2. A negatively charged ebonite rod will
   a. attract another negatively charged ebonite rod. b. repel another positively charged rod. c. attract another positively charged rod. d. attract the north pole of a bar magnet.
3. Electrons are
   a. inside the nucleus of an atom. b. positively charged. c. outside the nucleus.
4. When bodies are charged by rubbing
   a. electrons move. b. protons move. c. the nucleus of atoms shift because of friction and cause charges.

2. *Differentiate between the following pairs:*

1. conductor and insulator.
2. electron and proton.
3. positive and negative charges.
4. a bar magnet and an electrically charged ebonite rod.

3. *Fill in the blanks.*

1. A glass rod rubbed with fur is ________ charged.
2. Unlike charges ________ each other.
3. The nature of the charge on a body depends on the ________ by which it is rubbed.
4. The kind of charge developed when an ebonite rod is rubbed with fur is called ________.

4. *Draw and mark the parts of an electroscope.*

5. *Write short notes on*

1. What is meant by electric charges?
2. What is the theory of electrification?
3. What are conductors and insulators? Mention five insulators and five conductors.

6. *Answer the following in detail :*

1. What is meant by a positive charge and negative charge? Describe an experiment to show that like charges attract and unlike charges repel.

2. The kind of charge a body gets depends also on the substance with which you rub it. *When two substances are rubbed together, the substance which gives up electrons more easily gets a positive charge and the other substance gets a negative charge.* Now, an ebonite rod X, is rubbed with fur. Another ebonite rod Y is rubbed with flannel. Describe how you would test whether the charge on X is the same as that on Y
   (a) using an electroscope.
   (b) without using an electroscope.

9. Electricity

Structure of the atom - electric circuits - potential difference - effects of a current (heating, lighting, magnetic and chemical) - discharge of electricity through gases.

In the previous chapter we learnt about electric charges. We know that electric charges are produced by the transfer of electrons. An electric current is the flow of negative electric charges through a conductor.

Like other quantities, charges can also be measured. An electric charge is measured in coulombs, (symbol C). The smallest negative charge we can think of now is that of an electron. The charge on the electron is very small indeed. It is about 0.000,000,000,000,000,000,16 coulombs, or 1.6×10^{-19} coulombs.

Measuring the flow of charges or the electric current through a conductor is similar to measuring the 'water current' through a pipe. We measure the quantity of water in cubic centimetres (cm^3), i.e., as the volume of water that passes a point in the pipe per second. So, you might find, for example, that in a pipe, the rate of flow of water is $10cm^3$ per second. If the water flows twice as fast, there would be a rate of flow of $20cm^3$ per second.

Similarly, if 10 coulombs of electric charge flows through a conductor in one second, we can say that there is an electric current of 10 coulombs per second in the conductor. Electric current is measured in *amperes* (A).

A current of 1 ampere means a rate of flow of one coulomb of charge per second through the conductor.

But how do charges move? Since electric current is actually the movement of electrons, we must look once more at the structure of the atom to see why an electric charge moves from one place to another.

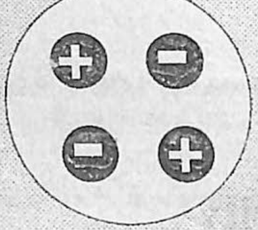
9.1 The structure of an atom

The ancient Greeks believed that all matter was composed of atoms. The word 'atom' comes from a Greek word which means 'indivisible'.

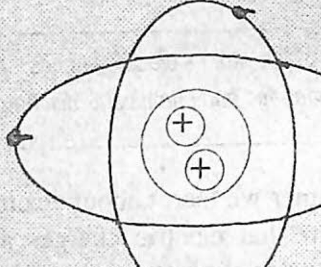
The Greeks believed that if something was divided until it could be divided no more, the last was an atom. An English chemist and mathematician called John Dalton, in 1803, became the first man to develop a Scientific atomic theory. Dalton, we could say, began the scientific study of atoms. But, exactly what an atom was and how it worked was not explained. Scientists have puzzled for a long time over what makes up the inside of an atom. They have used different models to try to explain this problem.

Activity 1: *Scientists have suggested various theories regarding what they believe a model of an atom should be. The diagrams below show some of them. Study them carefully and try to understand the theories and find out more information about the scientists who put forward these theories.*

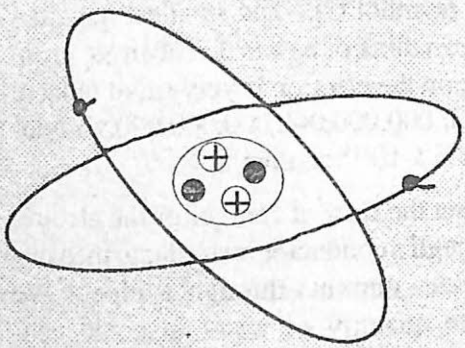
Christmas pudding model



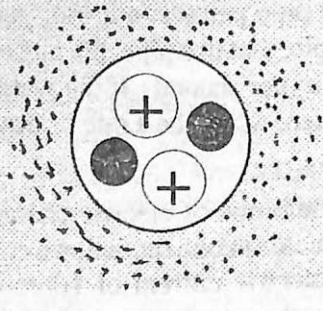
Nuclear model (Rutherford)



Neutrons discovered in nucleus (Chadwick)



Modern ideas - hazy cloud of electrons around nucleus



At the beginning of this century, scientists still imagined the atom to be rather like a solid Christmas pudding. They thought atoms were indivisible. However, the discovery of radioactivity helped to show that this picture was wrong.

Further experiments showed that the nucleus of an atom contains two different types of particles, the proton and the neutron. This has been generally accepted as the modern theory of atoms.

The proton has a positive charge equal in size but opposite in charge to that of an electron. It has a mass about 200 times that of an electron.

The neutron has no charge. Its mass is almost the same as that of the proton. The atoms of different elements contain a particular number of protons, neutrons and electrons.

The electron has a negative charge and the number of electrons in an atom will be equal to the number of protons. These electrons move around the nucleus in definite orbits, rather like the planets around the sun in our solar system. The electrons are kept from flying away from the orbits due to the attractions existing between the electrons and the protons in the nucleus.

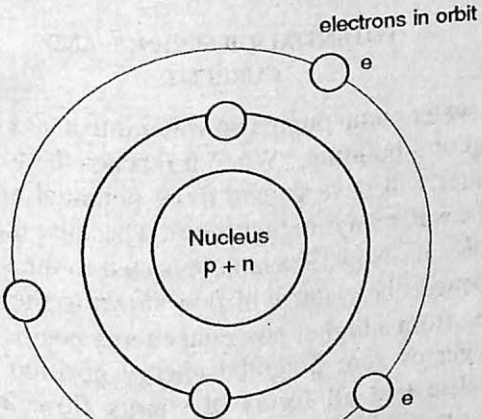


Fig. 9.1 Stucture of an atom

The number of protons in the nucleus is called the proton number or *atomic number*. This is also equal to the number of electrons in the atom.

The number of protons and neutrons in the nucleus is called the *mass number* (or atomic weight).

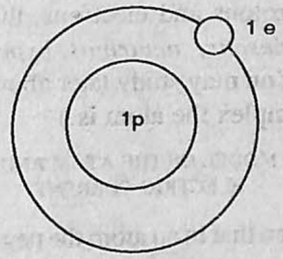


Fig. 9.2 Hydrogen atom

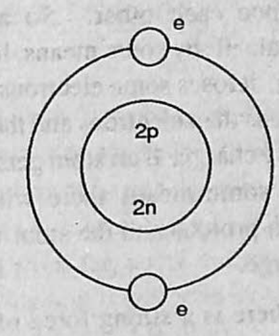


Fig. 9.3 Helium atom

The simplest atom is that of hydrogen with one proton and one electron. Then there is the helium atom with two protons, two neutrons and two electrons. This is often written as:

Atomic weight →4
He
Atomic number →2

(The symbol for radioactive carbon is $^{14}_{6}C$. How many protons are there in the nucleus of a radioactive carbon atom? How many neutrons are there in its nucleus? How many negatively charged electrons are there around its nucleus?

This is a simplified model of the modern ideas about the atom. We can use this model to explain the nature of electric currents as well as other things.

(Remember, anything we know about the atom may be changed tomorrow. Scientists are constantly discovering new things about the atom as 'atom smashing' machines are being built. In fact, scientists have found more than 20 different particles in the core of the atom. Other than the neutrons, protons and electrons, there are particles like *mesons, neutrinos, hyperons,* etc in the atom. You may study later about how wonderfully complex the atom is.)

MODEL OF THE ATOM AND ELECTRIC CURRENT

We have seen that in an atom the negative charge of the electrons and the positive charge of the protons balance each other. So an atom is usually neutral. If, by some means, like friction from rubbing, it loses some electrons, there will be more protons than electrons and the atom will have a positive charge. If an atom gets additional electrons by some means there will be more electrons than protons and the atom will have a negative charge.

Usually, there is a strong force of attraction between the negative electrons around an atom and the positive nucleus. The electrons are strongly bound to the nucleus. But, in some substances, like metals, some of the electrons are relatively free to move. Such materials make good conductors of electric currents, because the free electrons can move and pass the charge from one point to another. Electric current, thus passes through a conductor because of the movement of the free electrons.

So, we can say that electric current is actually the flow of electrons. We know that electrons being negative, will flow from a negatively charged part to a positively charged part through a conductor. But what makes the electrons flow?

9.2 Electric circuit

A single electric bell is represented by two lines in circuit diagrams ⊣⊢—. The long thin line represents the positive terminal and the short thick line represents the negative terminal. When two or more cells are connected together we get a battery, represented by —|⊢|⊢|⊢—

Activity 2: *Connect the positive pole of a dry cell to one terminal of a torch bulb (Fig. 9.4) and the negative pole of the cell to the other terminal of the bulb. The bulb lights up.*

An electric current has passed from one pole of the cell to the other pole. The connecting wires and the bulb, conducted the electric current. When an electric current is able to pass from one pole to another, we say, a circuit is complete or closed.

A circuit is the path of an electric current.

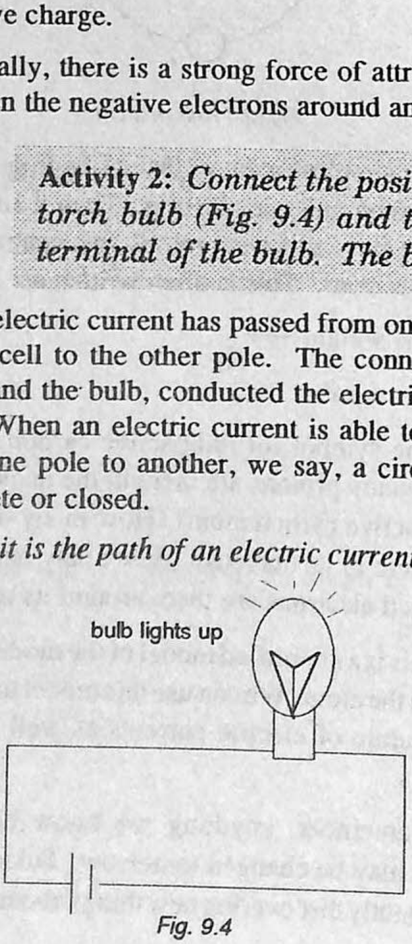


Fig. 9.4

POTENTIAL DIFFERENCE AND CURRENT

A water pump pumps up water into a tank at the top of a building. When it reaches the top, the water will have gained more potential energy. The water stays in that position because the tank holds it. Now, if a tap connected to the tank is opened, the water will flow down to the earth; i.e., from a higher potential energy position to a lower or zero potential energy position. We realise that all forms of energy flow from a position of greater potential energy to lower levels till energy levels are equalized. Heat, as you know, is transferred from a hotter body to a cooler one (if they are in contact) till the two bodies have the same temperature. Electric energy also behaves in the same way. An electric current flows through a wire connected to the two poles of a cell because there is a difference in the electrical potential between the two poles. The current will flow till the potential difference is zero.

The current through a circuit will depend on the electrical pressure difference between the ends of the circuit.

"Electrical pressure" is called *potential difference* (p.d.). Potential difference is measured in *volts* .

The potential difference between two points is 1 volt, if one joule of work done is when 1 coulomb of charge moves from one point to the other In circuit diagram, a voltmeter is represented by Ⓥ .

You've already learnt that current is measured in amperes. An *ammeter* is used to measure the electric current in a circuit which is represented in circuit diagrams by the symbol Ⓐ .

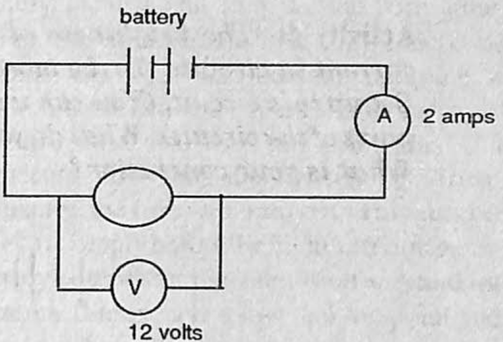


Fig. 9.5

DIRECTION OF CURRENT AND DIRECTION OF ELECTRON FLOW

You know that in an electric circuit, electrons flow from the negative terminal to the positive terminal. But, before the electron nature of current was discovered, it was thought that current flowed from the positive terminal to the negative. This is still followed as a convention in all circuit diagrams (Fig. 9.6) .

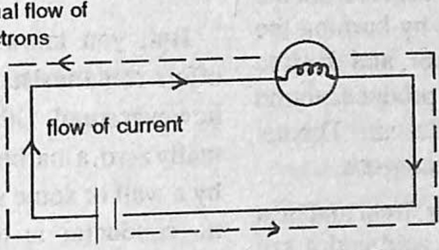
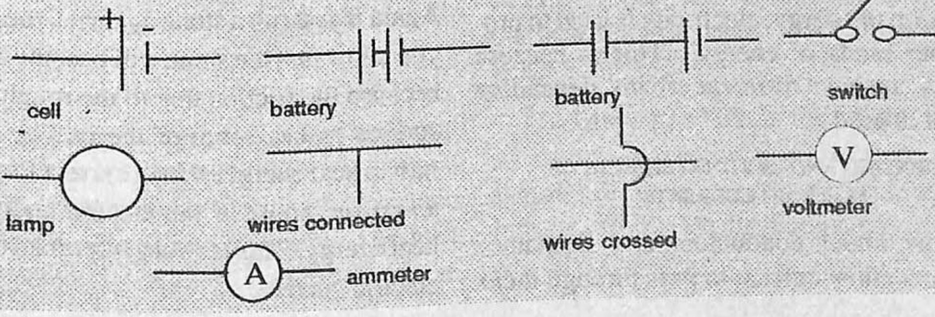
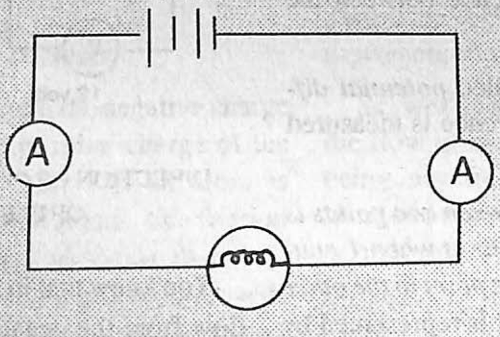


Fig. 9.6 Direction of current flow

Activity 3: *Copy the following symbols on a sheet of paper and paste it to a cardboard sheet. The symbols are used in figures showing electrical circuits. Leave space for new symbols you will have to use as you learn more about the electricity.*



Activity 4: *The brightness of lamps is only a rough guide to the current in circuits. To be more accurate, we must use an ammeter. Set up this circuit. (You can use one ammeter and put it in different parts of the circuit). What do you notice about the ammeter readings? What is your conclusion?*



9.3 Effects of electric currents

Electricity is a form of energy. It is the ability to do work. For instance, to run a car's motor, a force must be used. Something must provide the force. That 'something' is what comes from the petrol. This in turn is let loose by burning the petrol in the cylinder of the motor, and the free energy, is released. These forces produce motion through the gears and wheels of a car. The net result is that the car's engine does work.

Similarly when a candle burns, light and heat energy are released. When an acid and a salt react, chemical energy is involved. During photosynthesis, plants use light energy to make food from water and carbon dioxide.

Thus one form of energy can be changed to another form.

As a form of energy, electricity is used to produce other kinds of energy. This is because electricity can have different effects, depending on how it is used.

I. HEATING AND LIGHTING EFFECTS OF ELECTRIC CURRENTS

You know about conductors and insulators. Conductors allow current to pass through them. But there is no perfect conductor. All substances, at normal conditions, offer at least some resistance to the flow of current. We can compare this to the effect of friction. A very smooth surface, for instance offers very little friction.

But, you know, even the smoothest floor offers some resistance. There is some friction, however small. Otherwise, if the friction was actually zero, a marble would roll till it was stopped by a wall or some such thing. In a similar way, no conductor is totally conducting. There is always a little bit of resistance to the flow of energy.

Some conductors are like this. They allow currents to pass but offer much more *resistance* to its flow. Such conductors are called *resistors*. Again if you rub a stone against a rough surface, you know that the stone will become hot. This is because the friction due to the roughness of the surface makes some of the energy of rubbing turn to heat energy. When current flows through a *resistor*, some of the electric energy turns to heat energy. This is a very important effect of the electric current.

The resistance offered by a conductor to electric current is measured in ohms. In a circuit, a resistor is represented by a zig-zag line -/\/\/\-

Pure metals, generally have low resistance or are good conductors, whereas alloys have a much higher resistance.

An electric lamp filament, which is made of tungsten, may have a resistance of several hundred ohms while a small torch bulb filament may have a resistance of a few ohms.

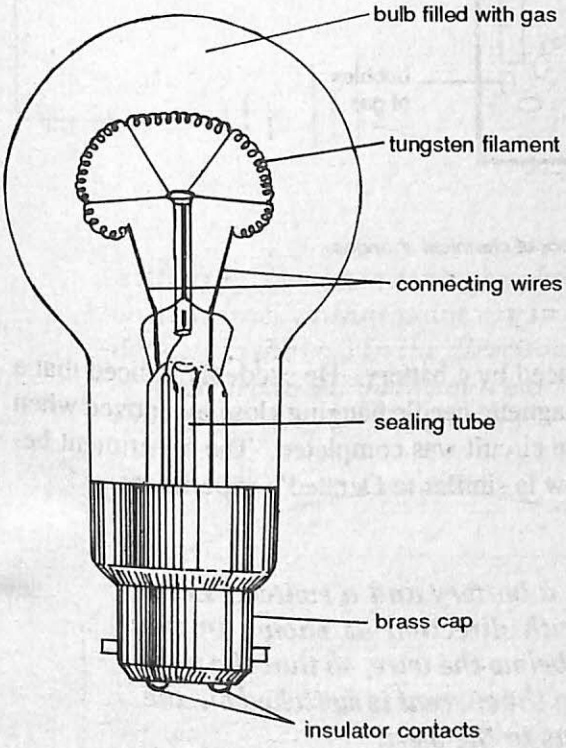


Fig 9.7 An electric bulb

The heating effect of electric current has many useful applications in the home. Electric heaters, for example, contain nichrome (a high resistance alloy) wire between their terminals. The heat produced when the wire is connected to the mains is sufficient to make the wire glow and give out considerable heat. Electric cookers, ovens and irons also contain nichrome wires which turns heat energy into light energy. The electric fuse also uses this principle. If high currents flow into the household wiring accidently, the fuse will burn out. This cuts off the electric supply before the high current can damage costly equipment like television sets and refrigerators. Fuses have a low melting point and the heat produced by high currents causes them to burn out.

Electric bulbs also use the heating and lighting effects of currents. When substances are heated till they are red or white hot, they give out light. In bulbs, the resistance wire is a coiled filament of tungsten (a metal with high resistance and high melting point). The air is pumped out of a bulb, so that the filament will not burn away when it is very hot. The air is sometimes replaced by neutral gases.

II. CHEMICAL EFFECTS OF A CURRENT

The flow of electric current through liquids was studied by Faraday and other scientists in the early 19th century. It was discovered that water was decomposed into hydrogen and oxygen when an electric current was passed through it.

Take dilute sulphuric acid in a beaker. Connect two pieces of pencil leads or carbon rods to cells through a bulb as shown in the figure. Dip the carbon rods in the sulphuric acid solution and switch on the circuit. The bulb glows. Look at the rods dipped in the sulphuric acid solution carefully. Can you see bubbles of gas coming out near both the rods? Switch off the circuit. What happens?

Electrolysis, which is the chemical effect of an electric current, is used (a) to produce pure samples of metals like copper, sodium, aluminium etc. (b) for electroplating, e.g., gold plating and silver plating

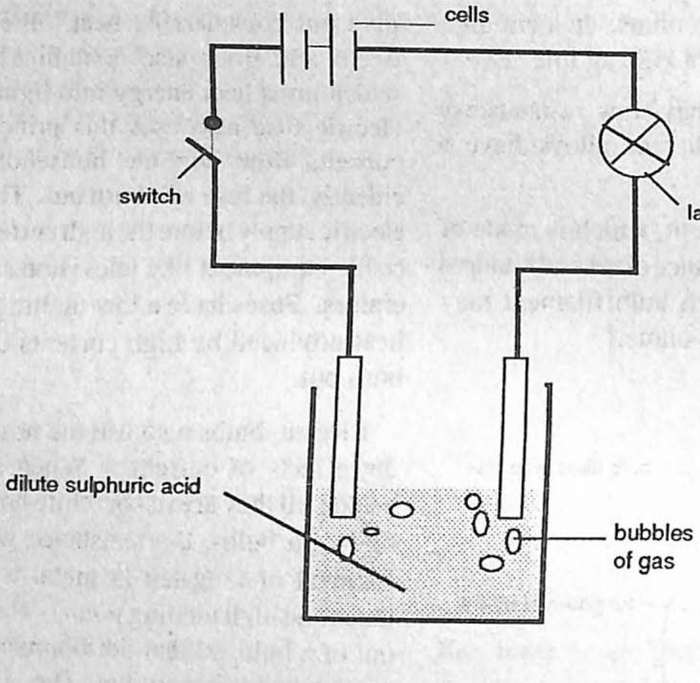
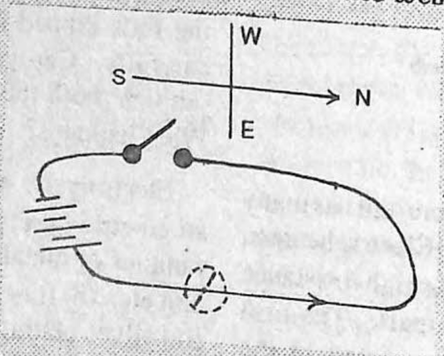


Fig. 9.8 Electric current brings about chemical changes

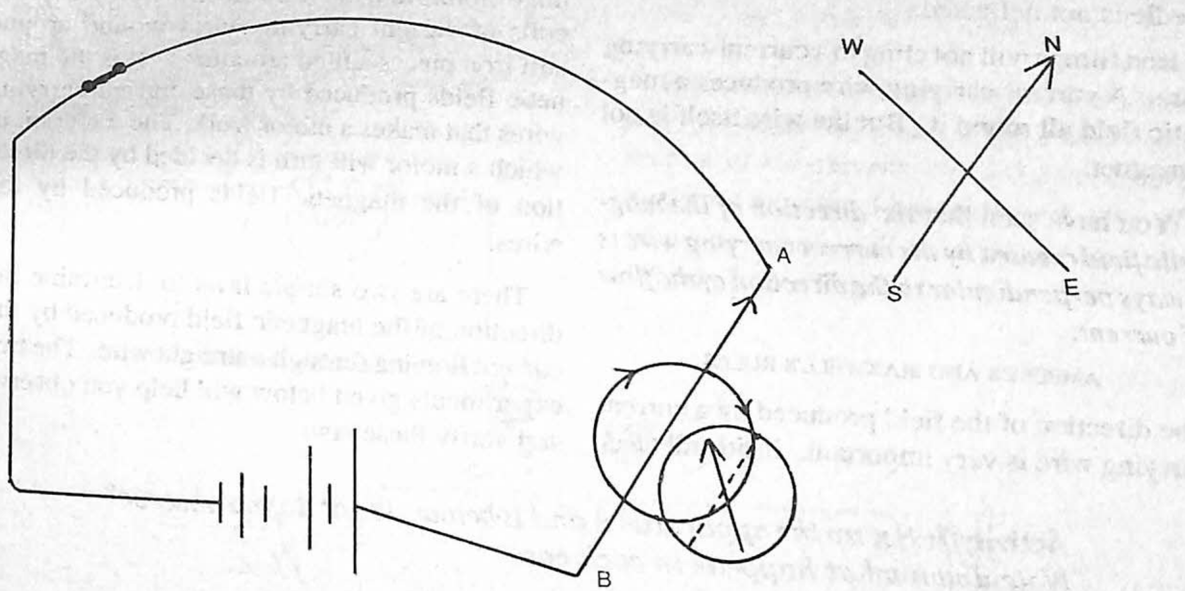
MAGNETIC EFFECTS OF AN ELECTRIC CURRENT

The discovery of the magnetic effect of a current, or electromagnetism, was made by a Danish physicist Hans Christian Oersted in 1819. Oersted was showing his students the current produced by a battery. He suddenly noticed that a magnetic needle hanging close by, moved when the circuit was completed. The experiment below is similar to Oersted's experiment.

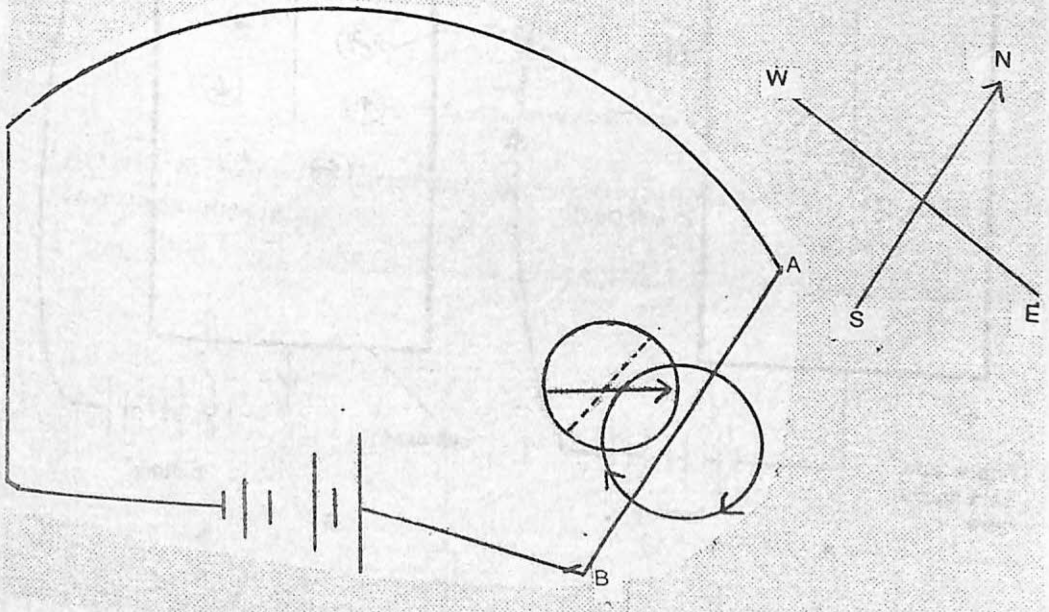
Activity 5: *Connect a piece of wire to a battery and a switch. Let a stretch of the wire lie in a north-south direction as shown in the figure. Now, place a compass needle below the wire, so that the wire is over the centre of the compass. When the current is switched on, the north pole of the compass needle turns to the west.*



This happens because the field lines around a straight, current carrying wire is circular (Fig. 9.9). The north pole of the compass needle is deflected perpendicular to the flow of current, in the direction of the field lines at that point.



Activity 6: *Hold the compass above the wire. Now the lines of force or field lines at that point are in the opposite direction. The needle deflects to the east in the direction of the field line. The magnetic line of force produced by the current is again perpendicular to the direction of the flow of the current.*



When the needle is place alongside the wire, the field line pulls the needle downwards. So, the needle is not deflected.

Iron filings will not cling to a current-carrying wire. A current-carrying wire produces a magnetic field all round it. But the wire itself is not a magnet.

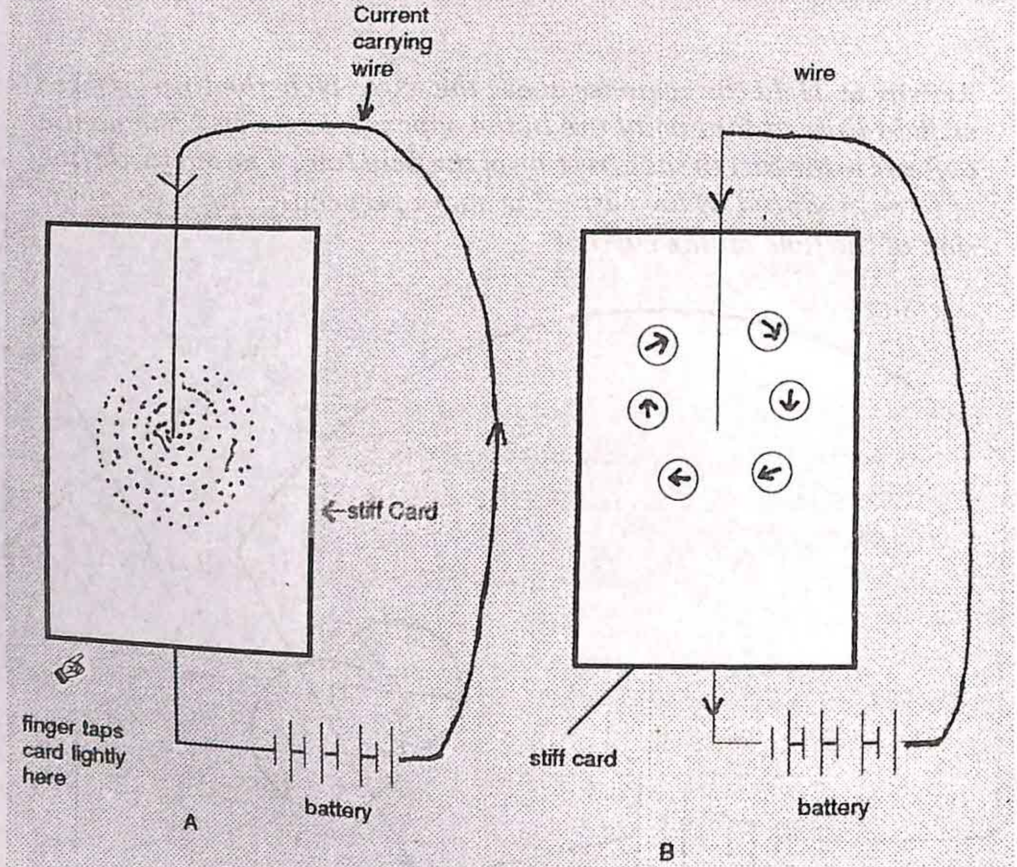
You have seen that *the direction of the magnetic field created by the current carrying wire is always perpendicular to the direction of the flow of current.*

AMPERE'S AND MAXWELL'S RULES

The direction of the field produced by a current carrying wire is very important. Inside all electrical motors, (from that of a tiny toy car and tape recorder; a kitchen mixie or a refrigerator, to the huge motors that move an electric train) there are coils of current carrying wires wound around soft iron pieces called armatures. It is the magnetic fields produced by these current-carrying wires that makes a motor work. The direction in which a motor will turn is decided by the direction of the magnetic fields produced by the wires.

There are two simple laws to determine the direction of the magnetic field produced by the current flowing through a straight wire. The two experiments given below will help you observe and verify these laws

Activity 7: *Set up the apparatus A and B below. What do you observe? Note down what happens in each case.*



The direction of the magnetic field near a current carrying straight wire can be found using *Maxwell's right hand grip rule.* If you hold the wire in the right hand so that the thumb points along the direction of the conventional current, the fingers then point in the direction of the magnetic field. (Fig. 9.10)

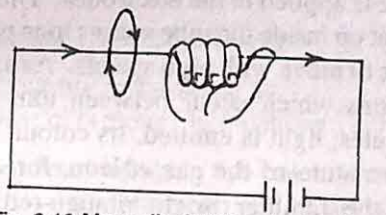


Fig. 9.10 Maxwells right hand grip rule

The direction of the magnetic field aroun current-carrying straight wire can also be fou using *Ampere's swimming rule.*

Ampere's swimming rule is as follow *Imagine a man swimming along a wire in the d rection of the current with his face towards magnetic needle. Then, the north pole of th magnetic needle will be deflected towards hi left hand.* See Fig. 9.11.

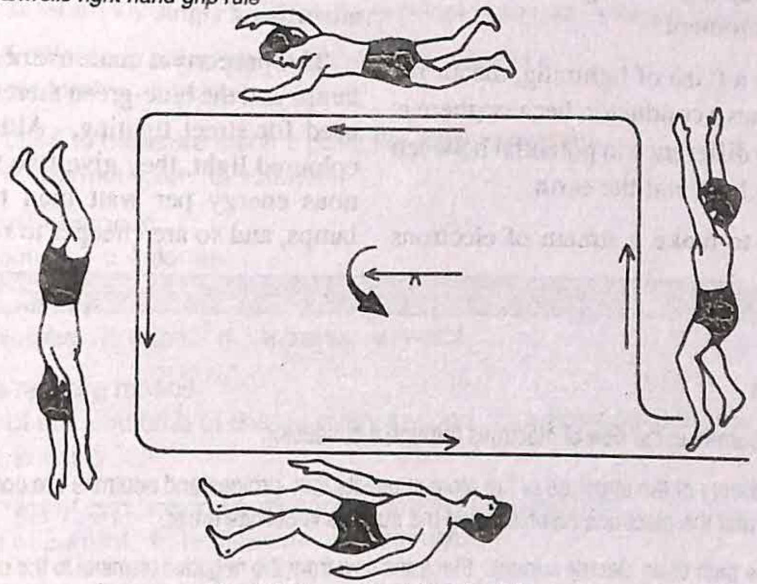
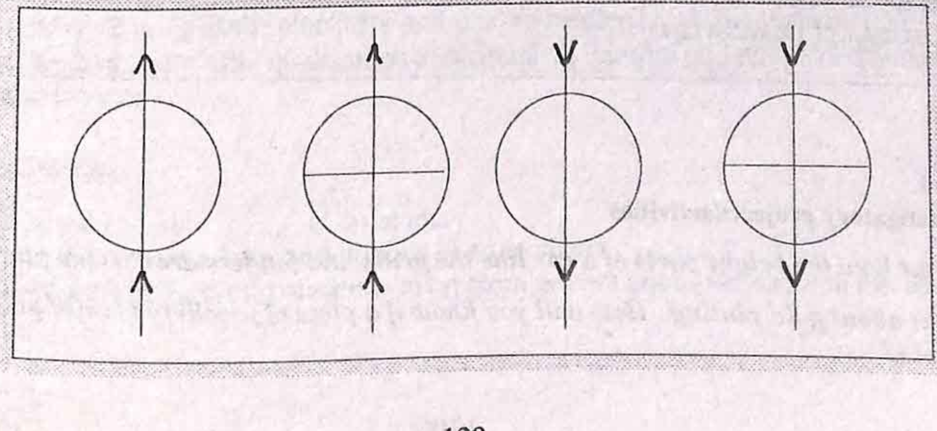


Fig. 9.11 Ampere's swimming rule

Activity 8: ***Copy the diagrams below, and indicate the positions of the compass needle.***



9.4 Discharge of electricity through a gas

We normally consider a gas, such as air, to be an insulator. In fact, it is. Otherwise, we would not be able to transmit electricity through wires carried overhead on poles. All the electricity would be conducted away by the air before it reached our homes. So, it is to our advantage that air is normally a poor conductor.

But, even gases conduct electricity under some conditions. If a very, very high voltage is applied between two points, a spark will jump across it. That means, a very high voltage has made air a conductor for a moment.

When there is a flash of lightning, the air for a moment becomes a conductor, because there is a very, very high difference in potential between the charge on a cloud and the earth.

It is possible to make a stream of electrons flow through a gas if it is at a very low pressure too.

DISCHARGE LAMPS

If some gas at low pressure is contained in a tube fitted with metal electrodes at each end, the gas glows with a characteristic colour when a high voltage is applied to the electrodes. The electric field set up inside the tube causes ions present in the gas to move with high speeds. As a result of collisions which occur between ions and gas molecules, light is emitted. Its colour depends on the nature of the gas. Neon, for example, gives the familiar bright orange-red seen in advertising signs.

This property is made use of in sodium vapour lamps and the blue-green mercury vapour lamps used for street lighting. Although these emit coloured light, they give five times more luminous energy per watt than the best filament lamps, and so are cheaper to run.

Basic concepts

1. The electric current is the flow of electrons through a conductor.
2. The modern theory of the structure of the atom suggests that protons and neutrons are concentrated in the nucleus and the electrons revolve round the nucleus in definite orbits.
3. A circuit is the path of an electric current. Electrons flow from the negative terminal to the positive terminal.
4. Electrical energy can be transformed to heat, light, magnetic and chemical energy.
5. The Maxwell's right hand grip rule and the Ampere's swimming rules tells us the direction of flow of the electric current and the magnetic field ina current carrying wire.
6. Under special conditions, gas which is normally an insulator conducts electricity giving rise to flourescence and emission of ultraviolet rays.

Some investigatory projects/activities

1. *Find out how the bright parts of a car like the grills and fenders are chrome plated.*
2. *Find out about gold plating. How will you know if a piece of jewellery is solid gold or plated with gold?*

3. *Based on the principle of discharge tubes, write a report on how a television picture is produced on the screen.*

4. *How does a flash of lightning occur?*

REVISION TIME

I. Choose the correct answer:

1. Electric current is the result of
   a. the flow of protons. b. electrons. c. moving neutrons.

2. A current flows between two points in a conductor when
   a. they are magnetic north and south poles. b. when there is a difference in temperature between them. c. when there is difference in electrical potential between them.

3. Electric potential difference between two points is measured in
   a. amperes. b. coulombs. c. volts.

4. The instrument used to measure electric potential difference is the
   a. voltameter. b. thermometer. c. voltmeter.

5. The unit of electric charge is
   a. joules b. coulombs. c. calories.

6. Current is measured in
   a. volts. b. coulombs. c. ohms. d. amperes. e. watts.

7. A current of one ampere means
   a. a rate of flow of one coulomb of charge every second. b. a potential difference of one volt. c. one joule per second.

8. The chemical effect of currents in conducting solutions is known as
   a. heating effect of current. b. resistance. c. electrolysis.

9. A gas is
   a. always a poor conductor. b. always a good conductor. c. is usually a insulator, but conducts under special conditions.

II. Differentiate between the following pairs:

1. electron and proton. 2. static electricity and current electricity. 3. conventional direction of current and the direction of flow of electrons in a circuit. 4. current and potential difference. 5. insulators and resistors.

III. Fill in the blanks:

1. Protons are located in the _______ of an atom.
2. Normally the number of electrons and protons in an atom are _______ .
3. When the number of protons and electrons in an atom are not equal, we say that the atom is _____________ .

4. Electric current is the flow of charges because of moving _______ .
5. The path of an electric current is known as a _______ .

IV. *Draw labelled diagrams showing*

1. a simple electric circuit.
2. the magnetic effects of an electric current.

V. *Write short notes:*

1. The structure of the atom.
2. Conductors, insulators and resistors.
3. Heating and lighting effects of an electric current.
4. Chemical effects of an electric current.
5. Magnetic effects of an electric current.
6. State Maxwell's right hand grip rule.

VI. *Write detailed answers for the following:*

1. Under what conditions will gases conduct electricity.
2. Explain what happens when electricity passes through acidulated water.

TEST PAPER - 1
Chapter 1 to 4

Time : 1 1/4 hrs.

I. *Fill in the blanks:*

1. The smallest measurement that can be accurately taken with an instrument is its...............
2. A distance - time graph plots the distance moved by a body on the ....axis of a graph.
3. Change in velocity over time is known as ....
4. Force is given by mass multiplied by ....
5. If a body has uniform velocity, its distance - time graph will be a .... line.
6. If a body has negative acceleration, itsa distance - time graph will be a line curving ....
7. The rate at which a body changes its position is called ....
8. The rate of displacement of a body is called ....
9. Quantities which possess only magnitude are called ....
10. The water pressure in a tap on the ground floor is ....
11. When 1 gm. of water is heated through 1°c, the amount of heat supplied is ....
12. Water has a maximum density at .... °c.

II. *Differentiate between the following pairs :*

1. speed and velocity. 2. acceleration and uniform acceleration. 3. scalars and vectors. 4. resultant force and equilibrant force. 5. inertia of rest and inertia of motion. 6. mechanical advantage and velocity ratio of a simple machine. 7. density and relative density. 8. thrust and pressure. 9. quantity of heat and temperature. 10. evaporation and boiling.

III. *Define the following terms :*

1. least count. 2. mass. 3. speed, displacement, velocity and acceleration. 4. inertia. 5. centre of gravity. 6. efficiency of a machine. 7. relative density. 8. Archimedes principle. 9. internal energy. 10. specific heat.

IV. *Write short notes on the following:*

1. What is a vernier ?
2. When does a force do work ? How is the work done measured ?
   A man raises a mass of 15 kg through a distance of 2m and holds it there for 20 seconds. Calculate the amount of work done.
3. What is centre of gravity ? What are the factors affecting the stability of a body ?
4. What is relative density ? A relative density bottle weighs 14.5 gm when empty. It weighs 13.74 gm when filled with water and 34.8 gm when filled with spirit. What is the relative density of spirit ?
5. State Pascal's law of fluid pressure. The area of the smaller piston in an hydraulic press is 1·sq.m., and the area of the larger piston is 5 sq.m. How much weight can be raised on the larger piston by applying a force of 100 kg. on the smaller piston ?

6. How does atmospheric pressure vary with altitude ?
7. What is Archimedes principle ? A glass stopper weighs 100 gm. in air, and 60 gm. in water when completely immersed. Calculate the volume of the glass stopper.
8. What is meant by the apparent expansion of a liquid ?
9. Explain the anomalous or curious behaviour of water.
10. Distinguish between heat capacity and specific heat capacity of a substance. How many joules of heat is gained by a piece of iron of mass 100 gm. when its temperature rises from 20 °C to 80 °C? (Assume the specific heat capacity of iron to be 460 J/kg °C.).

V. *Answer the following questions in detail :*

1. Describe the steps in using vernier callipers to find the diameter of a steel cylinder.
2. What is meant by mechanical advantage, velocity ratio and efficiency of a machine ? Explain the relation between them taking the example of a pulley system or a lever.
3. How will you verify Archimedes principle ?
4. What do you mean by the internal energy of an object ? Which possesses greater internal energy, a gram of water at 100 °c or a gram of steam at the same temperature ?
5. What do you mean by the melting point of a solid ? Describe the cooling curve method of finding the melting point of wax. Illustrate your answer with diagrams.

TEST PAPER - II

Chapters 5 to 9

Time : 1-1/4 hrs.

I. *Fill in the blanks :*

1. When the angle of incidence is 45 ° the angle of reflection is ....
2. The image in a plane mirror is (i) .... , (ii) .... (iii) .... and (iv) ....
3. When the angle of incidence of a ray of light on a plain mirror is 45 °c, the angle between the incident ray and reflected ray is ....
4. The image in a .... mirror is always diminished and virtual.
5. Sound is caused by .... bodies.
6. Sound travels in the form of ....
7. In a uniform magnetic field the lines of force are .... to each other.
8. The actual movement of electrons in a current carrying wire are .... in direction to the direction of the conventional current.
9. At normal pressure and temperature, gases are .... conductors of electricity.
10. Gases conduct electricity if the pressure is .... and the voltage across two points in it is ....
11. The atom has a central core called the ....

12. The proton carries a .... charge.
13. The atomic number of an element is equal to the number of .... in its nucleus.

II. *Differentiate between the following pairs :*

1. concave and convex mirrors. 2. real and virtual images. 3. reflection and refraction. 4. concave and convex lenses. 5. transverse and longtitudinal waves. 6. musical notes and noise. 7. string instruments and reed instruments. 8. magnetism and static electric charge. 9. conductors and insulators. 10. neutrons and protons. 11. electrons and protons. 12. a charged body and neutral body. 13. static electricity and an electric current.

III. *Define the following :*

1. the laws of reflection. 2. the laws of refraction. 3. an echo. 4. a magnetic field. 5. the lines of force or field lines in a magnetic field.

IV. *Write short notes on the following :*

1. Explain with the help of a diagram the meaning of the terms - centre of curvature, pole, principal axis and aperture of a concave mirror.
2. With the help of diagrams show the different characteristics of the images of an object kept at various distances in front of a concave mirror.
3. What is refraction ? What causes it ?
4. What are the main differences between a converging and a diverging lens ?
5. How is sound produced ? Why can't sound travel through a vacuum ?
6. Explain the charging of a glass rod rubbed with silk in terms of electron movement.
7. What do you mean by an electric current ? Distinguish between the movement of electrons in a circuit and the conventional direction of current in a circuit.
8. Give a simple description of the modern ideas about the atom. How is it used to explain electricity ?
9. State Amperes rule and Maxwell's right hand grip rule.
10. Mention and explain the various effects which an electric current can produce.

V. *Answer the following questions :*

1. Mention the two main types of lenses. Draw ray diagrams to indicate the position, size and nature of images formed by lenses for various positions of the object.
2. With the help of diagrams, explain how a wave moves through a medium. Differentiate between the two types of waves.
3. What is sound pollution ? How can it be controlled ?
4. With the help of diagrams wherever necessary, explain the various effects of an electric current. How are these effects used in our everyday lives ?
5. What do you mean by electrical discharge through a gas ? Draw the diagram of a cathode ray tube and mark the parts. Mention two uses of the property of gases to conduct electricity under special conditions.

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